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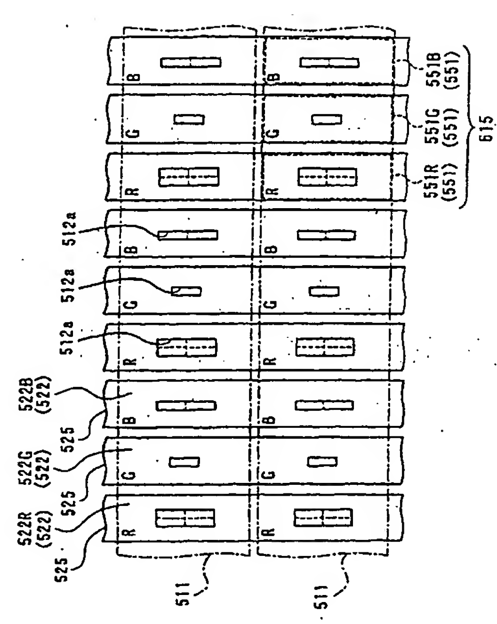
(54) Liquid crystal display device and electronic equipment

(57) The invention seeks to provide a color transflective liquid crystal display device wherein, even in the event that the spectral properties of the illumination light is not uniform, deterioration in color reproduction due to this can be suppressed, capable of display of similarly good colorization and high visual recognition for both the reflective mode and transmissive mode. A liquid crystal display device according to the present invention comprises a liquid crystal display panel having pixels (615) formed of multiple sub-pixels (551) each corresponding to different colors; and an illumination device; wherein the liquid crystal display panel comprises a transflective layer and a color filter (522) of color corresponding to the sub-pixels (551), with the transflective layer having transmissive portions for transmitting illumination light, wherein the transmissive portion is formed such that the area of the transmissive area corresponding to the transmissive portion of at least one sub-pixel of the multiple sub-pixels (551) and the area of the transmissive area corresponding to the transmissive portion at another sub-pixel, differ.

[FIG. 3]



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Description

[0001] The present invention relates to a liquid crystal display device and to electronic equipment, and particularly relates to a transflective liquid crystal display device with good coloring in both reflective mode and transmissive mode, and capable of color display that is highly visually recognizable, and also relates to electronic equipment using the same.

[0002] Reflective liquid crystal display devices are advantageous in that electric power consumption is low, since they do not have light sources such as back-lights, and have conventionally been widely used as accessory display units or the like for various types of portable electronic equipment and so forth. However, reflective liquid crystal display devices use external light, such as natural light like sunlight, or illumination light, to perform display, and accordingly there has been the disadvantage that the display is not readily visually recognized in dark situations.

[0003] Accordingly, liquid crystal display devices have been proposed wherein external light is used in bright situations in the same manner as with standard reflective liquid crystal display devices, and an internal light source such as a back-light is used in dark situations so as to make the display visible. That is to say, this liquid crystal display devices employs a display method serving as both reflective type and transmissive type, and the display method is switched between a reflective mode and transmissive mode according to the surrounding light, thereby enabling clear display even in dark surroundings while reducing electric power consumption, wherein external light contributes to the display when making reflection display, and light emitted from an illumination device (back-light) (this light hereafter referred to as "illumination light") contributes to display when making transmissive display.

[0004] In the present specification, this type of liquid crystal display device will be referred to as "transflective liquid crystal display device".

[0005] A transflective liquid crystal display device generally comprises a liquid crystal display panel wherein liquid crystal is sandwiched between a pair of substrates, and an illumination device provided on the other side of the liquid crystal display panel from the observation side for casting light on the substrate face of the liquid crystal display panel. Further, a reflective layer (transflective layer) having multiple opening portions is disposed on the substrate on the other side of the liquid crystal display panel from the observation side.

[0006] Also, in recent years, advancements in portable electronic equipment and office automation equipment has come to demand colorization of liquid crystal displays, and in many cases colorization is requested from electronic equipment having the above-described transflective liquid crystal display device, as well.

[0007] As for a color transflective liquid crystal display device to meet these demands, a transflective liquid crystal display device has been proposed which has a color filter. Such a color transflective liquid crystal display device with a color filter is arranged such that external light entering the liquid crystal display device in the reflective mode passes through the color filter, is reflected by the reflecting plate, and passes through the color filter again. Also, in the transmissive mode, light from the back-light also passes through the color filter. The same color filter is used for both the reflective mode and the transmissive mode.

[0008] With such color transflective liquid crystal display devices, a color display can be obtained by passing through the color filter twice when in the reflective mode and one when in the transmissive mode, as described above.

[0009] Accordingly, in the event that consideration is given to display when in the reflective mode where light passes through the color filter twice, for example, and accordingly a color filter with light colors is provided, display with good colorization cannot be readily obtained when in the transmissive mode wherein the light passes through the color filter only once. However, in the event that, in an attempt to solve this problem, consideration is given to the transmissive mode where light passes through the color filter once and accordingly a color filter with dark colors is provided, the display in the reflective mode where light passes through the color filter twice becomes dark, and consequently sufficient visual recognition cannot be obtained. Thus, with conventional color transflective liquid crystal display devices, it has been difficult to obtaining a display with similarly good colorization and high visual recognition for both the reflective mode and transmissive mode.

[0010] Also, illumination light emitted from illumination devices having LEDs (Light Emitting Diode) or cold cathode tubes or the like as a light source often do not have uniform luminance (intensity) throughout all wavelengths in the visible light range. Using such light with non-uniform distribution in luminance to perform transmissive display results in the spectral properties of the transmissive the liquid crystal display panel and emitting at the observation side being non-uniform, as well. As a results, there has been the problem of deterioration in color reproduction, such as in the case of using illumination light which has higher luminance in the wavelength corresponding to the blue color as compared to the luminance of other wavelengths for example, to perform transmissive display, the display will be bluish.

[0011] The present invention has been made to solve the above problems, and accordingly it is an object thereof to provide a color transflective liquid crystal display device wherein, even in the event that the spectral properties of the illumination light used for transmissive display is not uniform, resultant deterioration in color reproduction can be suppressed, and similarly good colorization and high visual recognition for can be obtained for both the reflective mode and transmissive mode with a color transflective liquid crystal display device having both the reflective mode and transmissive mode.

[0012] Also, it is an object of the present invention to provide electronic equipment comprising the above-described liquid crystal display device having excellent visual recognition properties.

[0013] To this end, the present invention has the following configuration.

[0014] The liquid crystal display device according to the present invention comprises: a liquid crystal display panel formed of liquid crystal sandwiched between a pair of mutually facing substrates, having pixels comprising multiple sub-pixels each corresponding to different colors; and an illumination device provided to the opposite side of the liquid crystal display panel as to the observation side, for illuminating the liquid crystal display panel with illumination light;

having a transflective layer disposed on the opposite side of the liquid crystal as to the observation side with a transmissive portion for transmitting the illumination light formed thereto, wherein the area of a transmissive area corresponding to the transmissive portion at at least one sub-pixel out of multiple sub pixels, and the area of a transmissive area corresponding to the transmissive portion at another sub-pixel, differ; and a color filter provided corresponding to each of the sub-pixels, for transmitting light of a wavelength corresponding to the color of each sub-pixel.

[0015] According to this liquid crystal display device, of the multiple sub-pixels making up the pixels, the percentage of transmissive area of one of the sub-pixels is made to differ from the percentage of transmissive area of other sub-pixels, thereby enabling the essential light transmittance ratio of the sub-pixels as to the illumination light of the illumination device to be arbitrarily selected. Accordingly, even in the event that there are irregularities in the spectral properties of the illumination light (luminance and quantity of light of the illumination light at each wavelength, spectral energy, etc.), the irregularities of the spectral properties of the like emitting from the liquid crystal display panel at the observation side can be reduced by compensating for he irregularities, and the percentage of the transmissive area of sub-pixels of one of the colors can be intentionally increased so as to select a display color with the liquid crystal display panel.

[0016] Now, with the present invention, the area of the transmissive area at each sub-pixel is preferably an area according to the spectral properties of the illumination light. This can realize excellent color reproduction even in the event that there are irregularities in spectral properties of the illumination light, by compensating for irregularities by making the percentage of transmissive area at each sub-pixel to be a percentage according to the spectral properties. Specifically, an arrangement may be conceived wherein the area of the transmissive area at each sub-pixel is an area according to the luminance of the wavelength of the illumination light corresponding to the color of the sub-pixel. That is, making the area of the transmissive area at a sub-pixel to be a color corresponding to a wavelength of the illumination light with great luminance smaller than the area of the transmissive area at a sub-pixel of a color corresponding to a wavelength of the illumination light with small luminance, light in the illumination light with more luminance can be made to have relatively less luminance in the observation light, and on the other hand, light in the illumination light with less luminance can be made to have relatively more luminance in the observation light. In this case, making the area of the transmissive area at each of the sub-pixels to differ for each sub-pixel corresponding to a different color (i.e., such that the area of the transmissive area is the same for sub-pixels corresponding to the same color) is advantageous in that the configuration can be simplified.

[0017] Also, a case may be conceived wherein the spectral properties of the illumination light differs according to the position within the substrate face of the liquid crystal display panel. In this case, the area of the transmissive area at each of the sub-pixels preferably is made to differ in configuration according to the position of the sub-pixel within the substrate face of the liquid crystal display panel. This arrangement allows the irregularities in spectral properties of the illumination light within the substrate face (i.e., inconsistencies between the spectral properties at one position within the substrate face and spectral properties at another position) can also be compensated for, so color reproduction can be improved in a more sure manner.

[0018] Also, a configuration may be conceived wherein the transmissive portion is an opening portion formed in the transflective layer corresponding to each of the sub-pixels. In the event that this configuration is employed, the manufacturing process can be simplified by a part of the transflective layer formed beforehand being removed by etching or the like. Now, an arrangement wherein one opening portion is provided for each sub-pixel may be conceived, but in this case, opening portions will be concentrated at a part of the areas of the sub-pixels, which could lead to occurrence of graininess of the display due to the opening portions. In order to solve this problem, an arrangement may be conceived wherein the opening portion comprises opening parts of generally the same area formed mutually separated, the number thereof according to the area of the transmissive area at the sub-pixels. Thus, the opening portions can be dispersed over the entirety of the sub-pixel, so occurrence of graininess such as described above can be avoided.

[0019] Also, as a different form of the transflective layer in a liquid crystal display device according to the present invention, the transflective layer may have the transmissive portion formed such that an area following at least one side of a plurality of sides defining each sub pixel serves as the transmissive area.

[0020] Also, in order to achieve the above objects, the liquid crystal display device according to the present invention, serving as a transflective liquid crystal display device which performs displaying by switching between a transmissive mode and a reflective mode, may comprise: a liquid crystal layer sandwiched between an upper substrate and a lower substrate facing one another; a transflective layer which has a transmissive area for transmitting light, and a reflective

area for reflecting incident light from the upper substrate side, and which is disposed on the inner side of the lower substrate; a color filter disposed on the upper side of the transflective layer, upon which are arrayed a plurality of pigment layers having different colors according to each of sub-pixels configuring a display area; and an illumination device disposed on the outward side of the lower substrate; wherein the pigment layers are formed over the entirety of an area overlapping the transmissive area in a planar manner, and an area overlapping the reflective area in a planar manner, wherein at least one color pigment layer is formed only at an area overlapping the reflective area in a planar manner; and wherein the area of the pigment layer formation area, where the pigment layers are formed, is formed such that the area thereof is different between at least one color pigment layer of the plurality of pigment layers of differing colors, and another color pigment layer.

[0021] With such as liquid crystal display device, the pigment layers are formed on the entire area overlapping the transmissive area in a planar manner and an area excluding a part of the area overlapping the reflective area in a planar manner, with a pigment layer formation area where each of the pigment layers are formed, and an area where the pigment layers are not provided at part of the area overlapping the reflective area (hereafter referred to as "pigment layer non-formation area") in a planar manner, so a part of the incident external light entering the liquid crystal display device when in the reflective mode passes through the pigment layer non-formation area, and the light obtained by passing through the color filter twice when in the reflective mode is a light combining uncolored light passing through the pigment layer non-formation area colored light passing through the pigment layer formation area.

[0022] On the other hand, light cast in from the back-light and passing through the transmissive area when in the transmissive mode passes through all pigment layer formation areas, and the light obtained by passing through the color filter once when in the transmissive mode is all colored light. Thus, the difference in concentration between the light obtained by passing through the color filter twice in the reflective mode and the light obtained by passing through the color filter once in the transmissive mode can be reduced.

[0023] Consequently, a color transflective liquid crystal display device with similarly good colorization and high visual recognition in display for both the reflective mode and transmissive mode, can be realized.

[0024] Moreover, with the liquid crystal display device according to the present invention, the area of the pigment layer formation area differs between a pigment layer of at least one color out of the pigment layers as to pigment layers of other colors, so adjustment of the color filter color properties can be made by changing the area of the pigment layer formation area, thereby enabling improved color reproduction, so a liquid crystal display device with excellent display quality can be realized.

[0025] Also, with the above-described liquid crystal display device, the pigment layers preferably comprise a red layer and green layer and blue layer, with the area of the pigment formation area preferably being formed such that the area thereof is smaller for the green layer as to the red layer and blue layer.

[0026] Arranging the liquid crystal display device thus allows further improvement in color reproduction in the event that the pigment layers comprise a red layer and green layer and blue layer, and a liquid crystal display device with even more excellent display quality can be realized.

[0027] Also, the above-described liquid crystal display device preferably further comprises a transparent film for smoothing the step between the pigment layer formation area and the area where the pigment layers are not provided.

[0028] Arranging the liquid crystal display device thus can do away with adverse effects due to the step between the pigment layer formation area and the area where the pigment layers are not provided, such as irregularities occurring in cell gaps causing irregularities in display owing to the step between the pigment layer formation area and the area where the pigment layers are not provided, and accordingly the reliability of the liquid crystal display device can be improved.

[0029] With the above-described liquid crystal display device, the transmissive area is formed by the transflective layer being opened in a window-like manner.

[0030] Also, the above-described liquid crystal display device may be configured such that band-shaped transparent electrodes are disposed on the inner side of the lower substrate, and wherein a band-shaped transmissive area is formed in the transflective layer by the transparent electrode pattern width being formed wider than the transflective layer pattern width.

[0031] With the above-described liquid crystal display device, the transflective layer is preferably formed of aluminum or an aluminum alloy, with the pigment layer containing a blue layer, and the area of the pigment layer formation area being provided so that the blue layer is smaller in comparison to the red layer.

[0032] With the liquid crystal display device configured thus, the area of the pigment layer formation area is provided so that the blue layer is smaller in comparison to the red layer, so even in the event that the light reflected by the transflective layer is colored blue, due to the transflective layer being formed of aluminum, correction is made by passing through the color filter twice, so a liquid crystal display device with excellent color reproduction and high display quality can be realized.

[0033] Also, with the above-described liquid crystal display device, the transflective layer is preferably formed of silver or a silver alloy, with the pigment layer containing a red layer and blue layer, and the area of the pigment layer

formation area being provided so that the red layer is smaller in comparison to the blue layer and the blue layer is greater.

[0034] With the liquid crystal display device configured thus, the area of the pigment layer formation area is provided so that the red layer is smaller in comparison to the blue layer and so the blue layer is larger, so even in the event that the light reflected by the transflective layer is colored yellow, due to the transflective layer being formed of silver, correction is made by passing through the color filter twice, so a liquid crystal display device with excellent color reproduction and high display quality can be realized.

[0035] Also, with the above-described liquid crystal display device, the color properties of the color filter are preferably adjusted by changing the area of the pigment layer formation area.

[0036] With such a liquid crystal display device, the difference in concentration between the light obtained by passing through the color filter twice in the reflective mode and the light obtained by passing through the color filter once in the transmissive mode can be reduced, while improving color reproduction. Consequently, a color transflective liquid crystal display device with display of similarly good colorization, high visual recognition, and excellent color reproduction, for both the reflective mode and transmissive mode, can be realized.

[0037] Also, in order to achieve the above objects, the liquid crystal display device according to the present invention, serving as a transflective liquid crystal display device which performs displaying by switching between a transmissive mode and a reflective mode, may comprise: a liquid crystal display panel formed of a liquid crystal layer sandwiched between a mutually facing upper substrate and lower substrate, having pixels making up a display area comprising multiple sub-pixels each corresponding to different colors; and an illumination device provided to the opposite side (outer side of the lower substrate) of the liquid crystal display panel as to the observation side, for illuminating the liquid crystal display panel with illumination light;

having a transflective layer disposed on the opposite side (inner side of the lower substrate) of the liquid crystal layer as to the observation side; and a color filter provided above the transflective layer with a plurality of pigment layers of different colors corresponding to each of the sub-pixels arrayed thereupon, for transmitting light of a wavelength corresponding to the color of each sub-pixel;

wherein a transmissive portion for transmitting the illumination light is formed on the transflective layer, the transflective layer further comprising a transmissive area for transmitting light and a reflective area for reflecting incident light from the upper substrate side;

and wherein the transmissive portion is formed such that the area of the transmissive area corresponding to the transmissive portion at at least one sub-pixel of the plurality of sub-pixels, and the area of the transmissive area corresponding to the transmissive portion at another sub-pixel, differ;

and wherein the pigment layers are formed over the entirety of an area overlapping the transmissive area in a planar manner, and an area overlapping the reflective area in a planar manner, wherein at least one color pigment layer is formed at a part overlapping the reflective area in a planar manner;

and wherein the area of a pigment layer non-formation area where the pigment layers are not formed at at least one sub-pixel of the plurality of sub-pixels, and the area of a pigment layer non-formation area at another sub-pixel, differ.

[0038] With such a liquid crystal display device, the transmissive portion is formed such that the area of the transmissive area corresponding to the transmissive portion at at least one sub-pixel of the plurality of sub-pixels, and the area of the transmissive area corresponding to the transmissive portion at another sub-pixel, differ, and also the area of a pigment layer non-formation area where the pigment layers are not formed at at least one sub-pixel of the plurality of sub-pixels, and the area of a pigment layer non-formation area at another sub-pixel, differ.

[0039] Accordingly, with such a liquid crystal display device, the display colors and brightness are adjusted by changing the ratio of the transmissive area and reflective area in the sub-pixels between one of the multiple sub-pixels and another sub-pixel, and also the display colors and brightness are adjusted by adjusting the color properties of the color filter by changing the ratio of the area of the pigment layer formation area and the pigment layer non-formation area, between at least one color pigment layer of the pigment layers and another color pigment layer.

[0040] With conventional transflective liquid crystal display devices, increasing the transmittance ratio by enlarging the transmissive area such that a bright display can be obtained when in the transmissive mode has the problem in that the reflectivity decreases and the display becomes dark when in the reflective mode, so it has been difficult to realize a transflective liquid crystal display device wherein a bright display can be obtained in both the reflective mode and transmissive mode.

[0041] Conversely, with the above-described liquid crystal display device, even in the event that the transmittance ratio is improved by enlarging the transmissive area such that a bright display can be obtained when in the transmissive mode, sufficient reflectivity for a bright display when in the reflective mode can be obtained by enlarging the area of the pigment layer non-formation area, so there is no problem of the display becoming dark when in the reflective mode, even if the reflective area is smaller.

[0042] Thus, according to the above-described liquid crystal display device, the brightness can be effectively adjusted, and a bright display can be achieved whether in the reflective mode or the transmissive mode.

[0043] Further, with such a liquid crystal display device, the display colors are adjusted by changing the ratio of the transmissive area and reflective area in the sub-pixels, and also the display colors are adjusted by adjusting the color properties of the color filter by changing the ratio of the area of the pigment layer formation area and the pigment layer non-formation area for each of the pigment layers, so the display colors can be effectively adjusted, and extremely excellent color reproduction can be obtained.

[0044] . Moreover, the above-described liquid crystal display device has a pigment layer formation area and pigment layer non-formation area, so the difference in concentration of color between the light obtained by passing through the color filter twice in the reflective mode and the light obtained by passing through the color filter once in the transmissive mode can be reduced, so a color transflective liquid crystal display device with similarly good colorization and high visual recognition, for both the reflective mode and transmissive mode, can be realized.

[0045] Consequently, using the above-described liquid crystal display device enables a color transflective liquid crystal display device having extremely excellent display quality to be realized.

[0046] Also, in order to achieve the above objects, the electronic equipment according to the present invention comprises one of the above-described liquid crystal display devices.

[0047] For example, the liquid crystal display device according to the present invention may be used as a display device in various types of electronic equipment, such as various display devices like televisions or monitors, communication equipment such as cellular telephones or PDAs, information processing devices such as personal computers, and so forth.

[0048] According to the electronic equipment, even in the event that there are irregularities in spectral properties of the illumination light, this can be compensated for to realize a display with high color reproduction, thereby yielding electronic equipment having a liquid crystal display device with excellent visual recognition, so this is suitable for electronic equipment regarding which particularly high-quality display is required.

Embodiments of the present invention will now be described by way of further example only and with reference to the accompanying drawings, in which:-

Fig. 1 is a cross-sectional diagram illustrating the configuration of a liquid crystal display device according to a first embodiment of the present invention.

Fig. 2 is a graph illustrating spectral properties of the illumination light cast onto the liquid crystal display panel from the illumination device in the liquid crystal display device.

Fig. 3 is a plan view illustrating the positional relation between the transparent electrodes on the first substrate and the components formed on the second substrate of the liquid crystal display device.

Fig. 4 is a graph illustrating the transmittance ratio properties of the color filters corresponding to each color of the liquid crystal display device.

Fig. 5 is a graph illustrating spectral properties of the illumination light passing through the liquid crystal display panel and emitted at the observation side in the liquid crystal display device.

Fig. 6 is a graph illustrating spectral properties of the illumination light passing through the liquid crystal display panel and emitted at the observation side in the event that all opening portions in the reflective layer are of the same area.

Fig. 7 is a cross-sectional diagram illustrating an example of the configuration of a liquid crystal display device according to a second embodiment of the present invention.

Fig. 8 is a perspective view illustrating the principal portions of the liquid crystal display panel in the liquid crystal display device.

Fig. 9 is a plan view illustrating the positional relation between the pixel electrodes on the first substrate and the components formed on the second substrate of the liquid crystal display device.

Fig. 10 is a cross-sectional diagram illustrating the configuration of a liquid crystal display device according to a third embodiment of the present invention.

Fig. 11 is a graph illustrating the transmittance ratio properties of the color filters corresponding to each color in the liquid crystal display device.

Fig. 12 is a plan view illustrating the positional relation between the sub-pixels and reflective layer in the liquid crystal display device.

Fig. 13 is a CIE chromaticity diagram showing color coordinates of color display by the liquid crystal display device.

Fig. 14 is a plan view illustrating the positional relation between the transparent electrodes on the first substrate and the components formed on the second substrate, with a liquid crystal display device according to a modification of the present invention.

Fig. 15 is a diagram illustrating an example of a liquid crystal display device according to the present invention, and is a partial cross-secession view illustrating an example of a passive matrix transflective color liquid crystal display device, wherein the color filter is provided on the inner side of the lower substrate.

Fig. 16 is a diagram illustrating only the transflective layer and color filter and shielding film of the liquid crystal

display device shown in Fig. 15, wherein Fig. 16(A) is a plan view for describing the overlapping of the transflective layer and the color filter, and Fig. 16(B) is a cross-sectional view along A-A' shown in Fig. 16(A).

Fig. 17 is a diagram illustrating only the transflective layer and the color filter and the transparent electrodes on the lower substrate in the liquid crystal display device according to the fifth embodiment, wherein Fig. 17(A) is a plan view for describing the overlapping of the transflective layer and the color filter, and Fig. 17(B) is a cross-sectional diagram following line C-C' shown in Fig. 17(A).

Fig. 18 is a diagram illustrating another example of a liquid crystal display device according to the present invention, and is a partial cross-secession view illustrating an example of a passive matrix transflective color liquid crystal display device, wherein the color filter is provided on the inner side of the upper substrate.

Fig. 19 is a diagram illustrating only the transflective layer and color filter and shielding film of the liquid crystal display device shown in Fig. 18, wherein Fig. 19(A) is a plan view for describing the overlapping of the transflective layer and the color filter, and Fig. 19(B) is a cross-sectional view along B-B' shown in Fig. 19(A).

Fig. 20 is a diagram illustrating an example of another liquid crystal display device according to the present invention, and is a partial cross-sectional view illustrating an example of a passive matrix transflective color liquid crystal display device wherein transparent electrodes are directly provided on the transflective layer.

Fig. 21 is a diagram illustrating only the transflective layer and color filter and transparent electrodes on the lower substrate, in the liquid crystal display device shown in Fig. 20, wherein Fig. 21(A) is a plan view for describing the overlapping of the transflective layer and the color filter, and Fig. 21(B) is a cross-sectional view along line D-D' shown in Fig. 21(A).

Fig. 22 is a perspective view illustrating an example of a cellular telephone.

Fig. 23 is a perspective view illustrating an example of a wristwatch-type electronic device.

Fig. 24 is a perspective view illustrating an example of a portable information processing device, such as a word processor or a personal computer.

Fig. 25 is a diagram illustrating only the transflective layer and color filter and transparent electrodes on the lower substrate of the liquid crystal display device according to the test example 2, wherein Fig. 25(A) is a plan view for describing the overlapping of the transflective layer and the color filter, and Fig. 25(B) is a cross-sectional view of Fig. 25(A).

Fig. 26 is a diagram illustrating only the transflective layer and color filter and transparent electrodes on the lower substrate of the liquid crystal display device according to the test example 3, wherein Fig. 26(A) is a plan view for describing the overlapping of the transflective layer and the color filter, and Fig. 26(B) is a cross-sectional view of Fig. 26(A).

Fig. 27 is a diagram illustrating the results of measuring the light emitted from the liquid crystal display device according to the test example 1, wherein Fig. 27(A) is a chromaticity diagram of the light obtained in the reflective mode, and Fig. 27(B) is a chromaticity diagram of the light obtained in the transmissive mode.

Fig. 28 is a diagram illustrating the results of measuring the light emitted from the liquid crystal display device according to the test example 2, wherein Fig. 28(A) is a chromaticity diagram of the light obtained in the reflective mode, and Fig. 28(B) is a chromaticity diagram of the light obtained in the transmissive mode.

Fig. 29 is a diagram illustrating the results of measuring the light emitted from the liquid crystal display device according to the test example 3, wherein Fig. 29(A) is a chromaticity diagram of the light obtained in the reflective mode, and Fig. 29(B) is a chromaticity diagram of the light obtained in the transmissive mode.

Fig. 30 is a diagram illustrating the results of measuring the light emitted from the liquid crystal display device according to the test example 4, wherein Fig. 30(A) is a chromaticity diagram of the light obtained in the reflective mode, and Fig. 30(B) is a chromaticity diagram of the light obtained in the transmissive mode.

Fig. 31 is a diagram illustrating the spectral properties of the color filter used with the liquid crystal display device according to the test example 4, and is a graph illustrating the relation between the transmittance ratio of the color filter and the wavelengths.

Fig. 32 is a diagram illustrating the transflective layer and color filter in the liquid crystal display device according to an eighth embodiment.

Fig. 33 is a diagram illustrating the transflective layer and color filter in the liquid crystal display device according to a ninth embodiment.

[0049] The following is a description of the embodiments of the present invention, with reference to the drawings. The embodiments illustrate one form of the present invention, but do not restrict the invention, and modifications may be made arbitrarily within the scope of the present invention.

<A: First Embodiment: Liquid crystal display device>

[0050] First, the first embodiment, wherein the present invention is applied to a passive matrix transflective liquid

crystal display device, will be described with reference to Fig. 1. Note that in Fig. 1 and the subsequent drawings, the scale of the layers and members differ one from another, in order to make the layers and members of a recognizable size in the drawings.

[0051] As shown in Fig. 1, this liquid crystal display device has a liquid crystal display panel (liquid crystal panel) 500 configured of a first substrate (upper substrate) 3 and a second substrate (lower substrate) 2 applied one to another across a seal member 503 with liquid crystal (a liquid crystal layer) 4 sandwiched therebetween, and an illumination device (a so-called back-light unit) 5 disposed at the second substrate 2 side of the liquid crystal display panel 500. Also note that in the following description, the opposite side of the liquid crystal display panel 500 from the illumination device 5 as shown in Fig. 1 will be referred to as the "observation side". That is to say, the "observation side" is the side at which an observer viewing images displayed on the liquid crystal display device is situated.

[0052] The illumination device 5 has multiple LEDs 621 (only one is shown in Fig. 1) and a light guiding plate 622. The multiple LEDs 621 are arrayed facing the side edge of the light guiding plate 622, and cast light to this side edge face. The light guiding plate 622 is a plate-shaped member for guiding light from the LEDs 621 cast in from the side edge face to the substrate face of the liquid crystal display panel 500 (the surface of the second substrate 2) in a uniform manner. Also, a scattering plate or the like is applied to the face of the light guiding plate 622 facing the liquid crystal display panel 500 to scatter the light cast out from the light guiding plate 622 to the liquid crystal display panel 500 in a uniform manner, while a reflecting plate is applied to the opposite side face for reflecting light heading in the opposite direction from the liquid crystal display panel 500, toward the liquid crystal display panel 500 (both omitted in the drawings).

[0053] Now, Fig. 2 is a graph illustrating an example of spectral properties of the illumination light (the relation of the wavelength and luminance of the illumination light) irradiated to the liquid crystal display panel 500 from the illumination device 5.

[0054] That is, in the graph in Fig. 2, the horizontal axis shows the wavelength, and the vertical axis shows the luminance of the illumination light at each of the wavelengths, as a relative value wherein a predetermined luminance is set as "1.00" as a reference value. As shown in this drawing, in the present embodiment, a case is assumed wherein there are irregularities in the luminance in the illumination light over the wavelengths within the visible light range, i.e., wherein the spectral properties of the illumination light are not uniform. Specifically, while the luminance of the illumination light according to the present embodiment is greatest at a wavelength close to 470 nm which corresponds to blue through green light, the luminance at around wavelengths 520 nm or above corresponding to yellow light through red light is comparatively weaker. Though the details will be described later, according to the liquid crystal display device according to the present embodiment, even in cases of performing transmissive display using illumination light with such irregularities in spectral properties, the effects of the irregularities in the spectral properties in the light cast out at the observation side of the liquid crystal display panel 500 (i.e., the light viewed by the observer. Hereafter referred to as "observation light".) are suppressed, and good color reproduction can be realized. Note that with the present embodiment, a case is assumed wherein illumination light having the spectral properties shown in Fig. 2 is irradiated over the entire substrate face of the liquid crystal display panel 500.

[0055] Returning to Fig. 1, the first substrate 3 and the second substrate 2 of the liquid crystal display panel 500 are plate-shaped transmissive members, such as glass or quartz, plastic, etc.

[0056] Multiple transparent electrodes 511 are formed on the inner surface (the liquid crystal 4 side) of the first substrate 3. The transparent electrodes 511 are band-shaped electrodes extending in a predetermined direction (the left and right directions in Fig. 1), and are formed of a transparent electroconductive material such as ITO (Indium tin Oxide) or the like. Further, the surface of the first substrate 3 where the transparent electrodes 511 are formed is covered by an oriented film 15. This oriented film 15 is an organic thin film such as polyimide or the like, and has been subjected to rubbing processing for stipulating the orientation direction of the liquid crystal 4 when voltage is not applied.

[0057] Also, on the outer side of the first substrate 3 (the surface of the outer side) a phase difference plate 17 and an upper polarization plate 13 are layered and disposed in that order on the first substrate 3.

[0058] On the other hand, a reflective layer (transflective layer) 521 having multiple opening portions 521a (described in detail later) is formed on the inter (liquid crystal 4 side) surface of the second substrate 2, of a material having reflecting light, such as aluminum or silver for example. The incidental light from the observation side of the liquid crystal display panel 500 is reflected at the surface of this transflective layer 521 (more specifically, at the surface other than the area where the opening portions 521a are formed) and is cast out at the observation side, thereby realizing a reflective display. Now, the inner surface of the second substrate 2 is made to be coarse so as to form a scattering structure (unevenness) at the surface of the transflective layer 521, but this is omitted in the figures.

[0059] Also, a 1/4 wavelength plate 18 and a lower polarization plate 14 are disposed on the outer side (the surface of the outer side) of the second substrate 2.

[0060] Further, formed on the inner side surface of the second substrate 2 covered by the transflective layer 521 are a color filter 522 (522R, 522G, 522B) and a shielding layer 523, an overcoat layer (smoothing layer) 524 for smoothing the unevenness formed by the color filter 522 and the shielding layer 523, multiple transparent electrodes 525, and an

oriented film 9 the same as the above-described oriented film 15.

[0061] The transparent electrodes 525 are band-shaped electrodes formed on the surface of the overcoat layer 524 of a transparent electroconductive material. Now, Fig. 3 schematically shows the positional relation between the transparent electrodes 511 (shown by single-dot broken lines), on the first substrate 3, the transparent electrodes 525 on the second substrate 2, and the color filter 522. As shown in the figure, the transparent electrodes 525 extend in a direction intersecting the transparent electrodes 511 (vertical to the paper in Fig. 1). The liquid crystal 4 sandwiched between the first substrate 3 and second substrate 2 changes in orientation direction by voltage being applied between the transparent electrodes 511 and the transparent electrodes 525. In the following description, areas where the transparent electrodes 511 and the transparent electrodes 525 face one another as shown in Fig. 3 will be referred to as "sub-pixels 551 (551R, 551G, 551B)". That is to say, the sub-pixels 551 can also be described as the smallest units of areas wherein the orientation of liquid crystal changes according to application of voltage.

[0062] The shielding layer 523 is formed in a lattice-like shape so as to cover the gap portions between the sub-pixels 551 arrayed in matrix fashion (that is to say, areas other than the areas where the transparent electrodes 511 and the transparent electrodes 525 face one another), serving to shield the gaps between the sub-pixels 551. The color filter 522 is a layer formed of a resin material or the like corresponding to the sub-pixels 551, and as shown in Fig. 3, is colored, with a dye or pigment, either R (red), G (green), or B (blue). In the following, sub-pixels corresponding to the color filters 522R, 522G, and 522B, will respectively be referred to as sub-pixels 551R, 551G, and 551B. These three sub-pixels 551R, 551G, and 551B with mutually differing colors form a pixel (dot) 615, which is the smallest unit of the display image.

[0063] Now, Fig. 4 is a graph representing the transmittance ratio properties of each of the color filters 522R, 522G, and 522B, with the horizontal axis as the wavelength of incident light to the color filter 522, and the vertical axis as transmittance ratio (the percentage of light emitted as to the amount of incident light). As shown in the figure, the color filter 522R exhibits high transmittance ratio for light having a wavelength 600 nm or more which corresponds to red, the color filter 522G exhibits high transmittance ratio for light having a wavelength of 500 through 600 nm which corresponds to green, and the color filter 522B exhibits high transmittance ratio for light having a wavelength of 400 through 500 nm which corresponds to blue light.

[0064] Next, description will be made regarding the form of the opening portions 521a formed in the transflective layer 521.

[0065] First, the opening portions 521a are provided near the center of each of the sub-pixels 551 on the transflective layer 521. Illumination light form the illumination device 5 passes through the opening portions 521a and is emitted from the observation side of the liquid crystal display panel 500, thereby realizing transmissive display. In the following description, of the area of the sub-pixels 551, the area corresponding to the opening portions 521a, i.e., the area through which illumination light from the illumination device 5 passes, will be referred to as "transmitting area (transmissive area)".

[0066] Further, the opening portions 521a formed on the transflective layer 521 have the area thereof selected such that the area of the transmissive areas mutually differ for each of the three sub-pixels 551R, 551G, and 551B, making up each pixel 615. More specifically, the area of the opening portions 521a corresponding to each of the sub-pixels 551R, 551G, and 551B corresponds to the spectral properties of the illumination light emitted from the illumination device 5.

[0067] With the present embodiment, as shown in Fig. 2, of the illumination light emitted from the illumination device 5, the luminance of the wavelengths from blue light to green light is great, while the luminance of the wavelength corresponding to red light is comparatively small. Accordingly, with regard to the sub-pixels 551G where the green color filter 522G corresponding to the wavelength with the greatest luminance, the area of the opening portion 521a corresponding thereto is formed smaller in comparison to the sub-pixels 551R and 551B corresponding to the other colors. Conversely, with regard to the sub-pixels 551R where the red color filter 522R corresponding to the wavelength with the least luminance of the illumination light is, the area of the opening portion 521a corresponding thereto is formed larger in comparison to the sub-pixels 551G and 551B corresponding to the other colors. Fig. 3 shows an arrangement wherein the area ratio of the opening portions 521a corresponding to the respective sub-pixels 551R, 551G, and 551B is set at "sub-pixel 551R : 551G : 551B = 4 : 1 : 2".

[0068] Now, Fig. 5 is a graph illustrating the spectral properties of the observed light emitting to the observation side from the liquid crystal display panel 500 in the event that transmissive display is carried out with the above-described configuration. On the other hand, Fig. 6 illustrates the spectral properties of the observed light in the event that transmissive display is carried out with an arrangement wherein all transmissive areas are of the same area for all sub-pixels 551 (hereafter referred to as "conventional configuration"), as a comparative example with that shown in Fig. 5. In either drawing, the spectral properties of the observed light in the event that transmissive display is carried out using the illumination light having the spectral properties shown in Fig. 2, is shown. In both Fig. 5 and Fig. 6, the horizontal axis shows the wavelength, and the vertical axis shows the luminance of the illumination light at each of the observed light, in a relative manner wherein a predetermined luminance (the same luminance in both Fig. 5 and Fig. 6) is set as

"1.00" as a reference value.

[0069] As shown in Fig. 6, in the event that the conventional configuration is employed, the observed light visually recognized by the observer is light which has an extremely high luminance near the wavelength 470 nm. Accordingly, the image light visually recognized by the observer will be a blue-greenish image. Conversely, with the configuration according to the present embodiment wherein the area ratio of the transmissive areas in the sub-pixels 551R, 551G, and 551B is 4 : 1 : 2, the luminance in the observed light near the wavelength 470 nm is comparatively lower than that in the case shown in Fig. 6, as shown in Fig. 5. Accordingly, a situation wherein the image light visually recognized by the observer is a blue-greenish image can be avoided even in the event that transmissive display is carried out using illumination light wherein the luminance at wavelengths corresponding to blue through green colors is greater than the luminance at other wavelengths.

[0070] Thus, with the configuration according to the present embodiment, of the illumination light, light at wavelengths with relatively small luminance is sufficiently allowed to pass through the transflective layer 521, while passage of light at wavelengths with relatively great luminance through the transflective layer 521 is restricted, thereby suppressing the effects which irregularities in the spectral properties of the illumination light have on the observed light.

[0071] That is to say, the non-uniformity in the spectral properties of the illumination light is compensated for, so that good color reproduction can be realized.

<B: Second embodiment: Liquid crystal display device>

[0072] Next, the second embodiment, wherein the present invention is applied to an active matrix transflective liquid crystal display device, will be described. Note that the following description is made illustrating a case using TFDs (Thin Film Diode) which are two-terminal switching devices as switching devices. Also, of the components in the figures described below, the components which are in common with the components shown in Fig. 1 are denotes with the same reference numerals as in Fig. 1, and description thereof will be omitted.

[0073] First, Fig. 7 is a cross-sectional view schematically showing an example of the configuration of the liquid crystal display device according to the present embodiment, and Fig. 8 is a perspective diagram illustrating the configuration of the principal components of the liquid crystal display panel making up the liquid crystal display device. The cross-section along A-A' in Fig. 8 is equivalent to Fig. 7. As shown in these figures, multiple pixel electrodes 513 arrayed in matrix fashion, and multiple scanning lines 514 extending in a predetermined direction (the direction vertical to the paper in Fig. 7) in the gap portions of the pixel electrodes 513, are formed on the inner side surface of the first substrate 3. Each of the pixel electrodes 513 are formed of a transparent electroconductive material such as ITO or the like, for example. Further, each of the pixel electrodes 513 and the scanning lines 514 adjacent to the pixel electrodes 513 are connected by TFDs 515. Each of the TFDs 515 are two-terminal switching devices having non-linear current/voltage properties.

[0074] On the other hand, as with the liquid crystal display device according to the first embodiment above, on the inner side surface of the second substrate 2 are formed a transflective layer 521 having multiple opening portions 521a, a color filter 522 and a shielding layer 523, an overcoat layer 524 for covering the surface of the second substrate 2 where these are formed. Further, multiple data lines 527 extending in a direction intersecting with the scanning lines 514 are formed on the surface of the overcoat layer 524. As shown in Figs. 7 and 8, the data lines 527 are band-shaped electrodes formed of an transparent electroconductive material. Now, Fig. 9 shows the positional relation between the pixel electrodes 513 (shown by single-dot broken lines) and the data lines 527. As shown in the figure, the data lines 527 face the multiple pixel electrodes 513 arrayed in rows on the first substrate 3. With this configuration, the liquid crystal 4 sandwiched between the electrodes changes in orientation state by voltage being applied between the pixel electrodes 513 on the first substrate 3 and the data lines 527 on the second substrate 2. That is to say, with the present embodiment, the areas where the pixel electrodes 513 and the data lines 527 face one another are equivalent to the sub-pixels 551 (more specifically, sub-pixels 551R, 551G, and 551B, corresponding to the respective color filters 522R, 522G, and 522B).

[0075] As with the above-described first embodiment, opening portions 521a are formed at positions corresponding to near the center portion of each of the sub-pixels 551 on the transflective layer 521 with the present embodiment as well, as shown in Fig. 9. The area of each of the opening portions 521a is determined such that the percentage of the transmissive area in each of the sub-pixels 551R, 551G, and 551B, is a percentage corresponding to the spectral properties of the illumination light from the illumination device 5. Now, the present embodiment also assumes performing transmissive display using the illumination light having the spectral properties shown in Fig. 2 above. Accordingly, at the sub-pixel 551G where the green color filter 522G corresponding to the wavelength which has the greatest luminance of the illumination light, the area of the opening portion 521a corresponding thereto is smaller in comparison to the area of the opening portions 521a corresponding to the sub-pixels 551R or 551B corresponding to the other colors.

[0076] That is, the percentage of the transmissive area in the sub-pixel 551G is smaller than the percentage of the transmissive areas in the sub-pixels 551R or 551B of the other colors. Conversely, at the sub-pixel 551R corresponding

to the wavelength which has the smallest luminance of the illumination light, the area of the opening portion 521a corresponding thereto is greater and the percentage of transmissive area in the sub-pixel 551R is greater in comparison to that of the sub-pixels 551G or 551B of the other colors. In the example shown in Fig. 9, a case is illustrated wherein the area ratio of the opening portions 521a in the sub-pixels 551R, 551G, and 551B, is "4 : 1 : 2".

[0077] The same advantages as those of the first embodiment can be obtained by this configuration, as well.

<C: Third embodiment: Liquid crystal display device>

[0078] In the first and second embodiments, examples of a configuration wherein opening portions 521a are provided near the center of areas corresponding to the sub-pixels 551 of the transflective layer 521, with the transmissive area being positioned at the center of the sub-pixels 551, has been shown. Conversely, with the present embodiment, the transmissive areas are areas following the edges of the sub-pixels 551.

[0079] Fig. 10 is a cross-section diagram illustrating the configuration of the liquid crystal display device according to the present embodiment. Note that the components shown in Fig. 10 that are in common with the components in Fig. 1 shown above are denoted with the same reference numerals. As shown in the figure, the liquid crystal panel 500 according to the present embodiment differs from the liquid crystal panel 500 described in the above embodiments in that the color filter 522 (522R, 522G, 522B), shielding layer 523, and overcoat layer 524 are formed on the first substrate 3, and in that the transparent electrodes 511 and oriented film 15 are formed on the surface of the overcoat layer. Further, the transmittance ratio properties of the color filter 522 according to the present embodiment differs from the transmittance ratio properties of the color filter 522 according to the above-described embodiments shown in Fig. 4.

[0080] Now, Fig. 11 is a graph illustrating the transmittance ratio properties of the color filters 522R, 522G, and 522B, according to the present embodiment. As can be understood by comparing this drawing with the above-described Fig. 4, the color purity of the color filters 522 according to the present embodiment, and particularly the color purity of the color filter 522G corresponding to the green color is higher than the color purity of the color filters 522 according to the above-described embodiments. More specifically, this is as follows.

[0081] Now, let us take a numerical value Tmax/Tmin, obtained wherein Tmax represents the maximum transmittance ratio of each of the color filters 522 in the wavelength range of 380 nm through 780 nm and Tmin represents the minimum transmittance ratio in the same wavelength range, as a parameter for evaluating color purity (hat is to say, the greater the numerical value Tmax/Tmin is, the higher the color purity). At this time, while the numerical value Tmax/Tmin of the green color filter 522G shown in the above-described Fig. 4 is "1.8", the numerical value Tmax/Tmin of the color filter 522G according to the present embodiment is "8", and accordingly it can be understood that the color purity of the color filter 522G according to the present embodiment is markedly higher than the color purity of the color filter 522G according to the above-described embodiments.

[0082] Also, with the present embodiment, the form of the transflective layer 528 differs from that of the first and second embodiments. That is, in the above-described embodiments, examples of configuration were described wherein the form of the transflective layer 521 (more specifically, the form of the opening portions 521a in the transflective layer 521) is selected such that the areas positioned at the center of the sub-pixels serve as the transmissive areas. Conversely, with the present embodiment, the form of the transflective layer 528 is selected such that the areas following two opposing sides of the four sides defining each generally-rectangular-shaped sub-pixel 551 (the two sides extending in the Y direction) are made to be the transmissive areas. The following is a description of the specific form of the transflective layer 528, with reference to Fig. 12.

[0083] As shown in Fig. 12, the transflective layer 528 according to the present embodiment has multiple portions extending in the Y direction on the second substrate 2. On the other hand, the transparent electrodes 525 are of the same form as that shown in the above-described embodiments, but differ in that they are formed so as to cover the transflective layer 528. Thus, the transflective layer 528 according to the present embodiment is formed in stripes so as to correspond to the transparent electrodes 525. In other words, it can be said that transmissive portions (portions for transmitting illumination light from the illumination device) 528a are formed on the transflective layer 528 following the gap portions of the transparent electrodes 525. As a result of transmissive portions 528a formed thus being formed on the transflective layer 528, the areas following the opposing sides extending in the Y direction, of the four side defining the perimeter of the generally-rectangular-shaped sub-pixel 551, serve as transmissive areas, as shown in Fig. 12.

[0084] With the present embodiment as well, the form of the transflective layer 528 is selected such that the area of the transmissive area in at least one sub-pixel 551 differs from the area of the transmissive areas the other sub-pixels 551, as with the above-described first and second embodiments.

[0085] More specifically, as shown in Fig. 12, a width Wr of a reflective layer corresponding to a row of sub-pixels 551R and a width Wb of a reflective layer corresponding to a row of sub-pixels 551B are approximately equal, and a width Wb of a reflective layer corresponding to a row of sub-pixels 551G is wider than the width Wr and the width Wb. Accordingly, the area Sr of the transmissive area in the sub-pixel 551R and the area Sb of the transmissive area in the

sub-pixel 551B are approximately equal, while the area Sg of the transmissive area in the sub-pixel 551G is smaller than the area Sr or area Sb.

[0086] Here, a case where the ratio of area Sr and area Sg and area Sb is "Sr : Sg : Sb = 1.5 : 1 : 1.5" is assumed.

[0087] Now, as shown in Fig. 4, the transmittance ratio of the green color filter 522G shown in the above embodiment is markedly higher as compared to the transmittance ratio of the other color filters 522R or 522b of the other colors. Accordingly, in order to perform ideal white display using the color filter 522 having the transmittance ratio properties shown in Fig. 4 (i.e., color reproduction compensation), there is the need to make the area of the transmissive area in the green sub-pixel 551G markedly smaller than the area of the transmissive area in the other color sub-pixels 551R or 551B. Conventionally, the transmittance ratio of the color filter 522G having the transmittance ratio properties shown in Fig. 11 is suppressed to a lower transmittance ratio than the color filter 522G shown in Fig. 4, so the difference between the area of the transmissive area in the green sub-pixel 551G and the area of the transmissive area in the other color sub-pixels 551R or 551B does not need to be secured at as high a level as the case of using the color filter 522 shown in Fig. 4. That is to say, using the color filter 522G having the transmittance ratio properties shown in Fig. 11 does away with the need for making the area of the transmissive area in the green sub-pixel 551G all that smaller.

[0088] Now, Fig. 13 is a CIE chromaticity diagram indicating color coordinates of colors displayed by the liquid crystal display device according to the present embodiment. In Fig. 13, the color coordinates of colors displayed by a liquid crystal display device of a conventional configuration are shown as a comparative example with the present embodiment. Note that a "conventional configuration" is a liquid crystal display device which uses a color filter having the transmittance ratio properties shown in Fig. 13 and has the same area for the transmissive areas for all sub-pixels.

[0089] In the CIE chromaticity diagram, the color coordinates in the event of performing ideal white display is generally (x, y) = (0.310, 0.316), with this point being indicated in Fig. 13 by an "x". As can be clearly seen from the figure, the color coordinates in the case of performing white display with the liquid crystal display device according to the present embodiment is closer to the ideal white display color coordinates as compared to the color coordinates in the case of performing white display with the liquid crystal display device according to the conventional configuration. That is to say, good color reproduction can be realized with the liquid crystal display device according to the present embodiment.

[0090] The advantages of suppressing the effects which irregularities in the spectral properties of the illumination light may have on the observed light and realizing good color reproduction are obtained with the present embodiment as with the above-described embodiments.

[0091] As indicated in the present embodiment and the above-described embodiments, with the present invention, as long as the percentage of the transmissive area in one of the sub-pixels making up a pixel and the percentage of the transmissive area in the other sub-pixels making up the pixel differ, the form of the transmissive areas of the sub-pixels, i.e., the form of the transmissive portion (opening portion 521a or transmissive portion 528a) in the transflective layer 521 may be any form. Also, the term "transmissive portion" in the present invention means "a portion in the transflective layer through which illumination light from the illumination device is transmitted", and is not restricted to opening portions (i.e., holes) formed in the transflective layer.

<D: Modifications>

[0092] The above has been a description of an embodiment of the present invention, bit the above-described embodiment is only an example, and various modifications may be made to the above embodiment without departing from the essence of the present invention. Modifications such as given below may be conceived, for example.

<D-1: Modification 1>

[0093] In the above first and second embodiments, the arrangement is.such that the area of the opening portions 521a corresponding to the sub-pixels 551 is made to differ according to the spectral properties of the illumination light from the illumination device 5, but the arrangement may be as follows. That is, as shown in Fig. 14, the area of the opening portions 521a provided in the transflective layer 521 are generally the same, while on the other hand, the number of opening portions 521a provided for each sub-pixel 551 is of a number according to the spectral properties of the illumination light.

[0094] For example, in the above-described embodiments, the area ratio of the opening portions 521a corresponding to the sub-pixels 551R, 551G, and 551B, is "4 : 1 : 2" to correspond to the spectral properties of the illumination light illustrated in Fig. 2 above, but with the present modification, the ratio of the number of the opening portions 521a corresponding to the sub-pixels 551R, 551G, and 551B, is made to be "4 : 1 : 2", as shown in Fig. 4. The same advantages as those of the above embodiments can be obtained with this configuration as well. Also, as shown in the embodiments, while it is conceivable that graininess might occur in the image visually recognized by an observer as the results of deviation in the position of the opening portions 521a in the sub-pixels 615, in the event that the opening portions 521a are formed corresponding to only a part of the sub-pixels 551, but according to the configuration illustrated

by the present modification, the opening portions 521a can be scattered throughout the sub-pixels 551, and thus is advantageous in that such problems can be avoided.

<D-2: Modification 2>

[0095] In the above embodiments, the percentage of transmissive area in the sub-pixels 551 is made to differ for each of the sub-pixels 551 corresponding to the same color. Irregularities in the spectral properties of the illumination light can be sufficiently compensated for with this configuration in the event that the spectral properties of the illumination light from the illumination device 5 are the same through the entire face of the substrate surface of the liquid crystal display panel 500. However, there may be cases wherein the spectral properties of the illumination light from the illumination device 5 differ according to places in the substrate face. For example, some places in the substrate face may be irradiated with illumination light having the spectral properties shown in Fig. 2, while other places may be irradiated with illumination light having spectral properties other than those shown in Fig. 2.

[0096] In such cases, the percentage of the transmissive area may be changed according to the position of the sub-pixels 551 in the substrate face (i.e., the area of the opening portions 521a may be made to differ). For example, while the area ratio of the transmissive area in the sub-pixels 551R, 551G, and 551B, may be "4 : 1 : 2" at a pixel 615 situated at a position wherein illumination light having to the spectral properties illustrated in Fig. 2 is irradiated, the area ratio of the transmissive area in the sub-pixels 551R, 551G, and 551B, may be "3 : 1 : 2" at a pixel 615 situated at a position wherein illumination light having somewhat less luminance in the blue light through the green light as compared to the above illumination light is irradiated. In this way, there is no particular need for the percentage of the transmissive area of the sub-pixels 551 corresponding to the same color to be all the same throughout the sub-pixels 551. According to the present modification, in addition to the advantages shown with the above embodiments, non-uniformity of spectral properties of the illumination light in the substrate face can be compensated for, and thus is advantageous in that color reproduction can be improved in a more sure manner.

<D-3: Modification 3>

[0097] While the above embodiments illustrate examples wherein the illumination light from the illumination device exhibit the spectral properties illustrated in Fig. 2, it is needless to say that the spectral properties of the illumination light are not restricted to these. That is, even in cases of using illumination light exhibiting spectral properties other than those shown in Fig. 2 for transmissive display, the advantages of compensating for irregularities in the spectral properties of the illumination light can be compensated for and good color reproduction can be realized, by setting the area according to the spectral properties of the illumination light, such as making the area of the transmissive area in sub-pixels of a color corresponding to a wavelength of the illumination light with great luminance to be smaller than the area of the transmissive area in sub-pixels of a color corresponding to a wavelength with less luminance.

[0098] Moreover, the area of the transmissive area of the sub-pixels does not necessarily need to be according to the spectral properties of the illumination light. For example, arranging for the area of the transmissive area in the sub-pixels 551G corresponding to green or the area of the transmissive area in the sub-pixels 551B corresponding to blue (i.e., the area of the opening portions 521a corresponding to these sub-pixels 551) to be greater than the area of the transmissive area in the sub-pixels 551R corresponding to red regardless of the spectral properties of the illumination light enables the display to be intentionally made blue-greenish. That is, with the present invention, all that is necessary is for the area of the opening portion 521a in the transflective layer 521 be set such that the area of the transmissive area for one sub-pixel 551 to be different from the area of the transmissive area for another sub-pixel 551.

<D-4: Modification 4>

[0099] In the above third embodiment, an example is given regarding a case wherein the form of the transflective layer 528 is selected such that the areas following two opposing sides of the four sides defining each sub-pixel are made to be the transmissive areas, but the form of the transflective layer 528 may be selected such that the area following one side, three sides, or all sides (four sides) of the four sides is used as the transmissive area. That is to say, in the forming the transmissive area of the area following the edges of the sub-pixel, all that is necessary is to make an area following at least one of the multiple sides defining the sub-pixels to be the transmissive area. Also, in the third embodiment, an example is given of a transflective layer 528 with a form of being connected ling multiple sub-pixels 551, but the transflective layer 528 may be of a form separated for each pixel 551.]

<D-5: Modification 5>

[0100] Though the above embodiments illiterate an example of a case of using a stripe array, wherein the color filters

522 of the same color form a row, other forms of arraying the color filters 522, such as mosaic arrays or delta arrays, may be used.

[0101] Also, the above embodiments illustrate an example of a case wherein the transflective layer 521 is formed on the inner surface of the second substrate 2, but an arrangement may be conceived wherein the transflective layer 521 is formed on the outer surface of the second substrate 2. In short, a configuration wherein the transflective layer 521 is situated at the opposite side of the liquid crystal 4 as to the observation side will suffice.

<D-6: Modification 6>

[0102] Though the above second embodiment describes an example of an active matrix liquid crystal display device using TFDs 515 as the switching devices, the applicable scope of the present invention is not restricted to this, and can also be applied to liquid crystal display devices using three-terminal switching devices, of which TFTs (Thin Film Transistor) are representative. Note that in the case of using TFTs, an opposing electrode is formed on the entire face of one substrate, while multiple scanning lines and multiple data lines are formed on the other substrate so as to be extended in the directions of mutually intersecting, and pixel electrodes connected to both of these via TFTs are arrayed in matrix fashion. In this case, the areas where the pixel electrodes and the opposing electrode face one another function as the sub-pixels.

<D-7: Modification 7>

[0103] Though the above embodiments illustrated an example of a case wherein the transflective layer 521 and the transparent electrodes 525 (data lines 527 in the second embodiment) are formed separately, but an arrangement may be made wherein an electrode for applying voltage to the liquid crystal 4 is formed of an electroconductive material having light-reflecting properties, so that this electrode also functions as the transflective layer 521. That is, as shown in Fig. 1, the transflective layer 521 is not provided, and a reflecting electrode of the same form as the transparent electrode 525 is provided in the stead thereof. In this case, opening portions of the forms illustrated as examples in the above embodiments and modifications are provided at a portion of the areas of the reflecting electrode corresponding to the sub-pixels (i.e., the areas facing the transparent electrode 511 on the first substrate 30).

<E: Fourth Embodiment: Liquid crystal display device>

[0104] Fig. 15 is a diagram illustrating an example of the liquid crystal display device according to the present invention, and is a partial cross-sectional diagram illustrating an example of a passive matrix transflective color liquid crystal display device wherein a color filter is provided on the inner side of the lower substrate. Also, Fig. 16 is a diagram illustrating only the transflective layer and color filter and shielding film of the liquid crystal display device shown in Fig. 15, wherein Fig. 16(A) is a plan view for describing the overlapping of the transflective layer and the color filter, and Fig. 16(B) is a cross-sectional view along A-A' shown in Fig. 16(A).

[0105] Note that in the following drawings, the ratio of the film thickness and dimensions of the components are changed as appropriate to facilitate viewing of the drawings.

[0106] The liquid crystal display device shown in Fig. 15 has a schematic configuration comprising a liquid crystal panel (liquid crystal display panel) 1, and a back-light (illumination device) disposed at the rear side of the liquid crystal panel 1 (at the outer side of the lower substrate 2).

[0107] Also, the liquid crystal panel 1 has a schematic configuration comprising a liquid crystal layer 4 of an STN (Super Twisted Nematic) liquid crystal or the like sandwiched between the lower substrate 2 and upper substrate 3 disposed facing one another.

[0108] The lower substrate 2 is formed of glass or resin or the like, with a transflective layer 6 disposed on the inner face side of the lower substrate 2, having a color filter 10 layered on the upper side of the with transflective layer 6, with a shielding film 41 of a black-colored resin material or the like provided between the pigment layers 11R, 11G, and 11B making up the color filter 10. Also, a transparent smoothing film 12 for smoothing the unevenness formed by the color filter 10 is layered on the color filter 10. Further, stripe-shaped transparent electrodes (segment electrodes) 8 formed of a transparent electroconductive film such as indium tin oxide (hereafter referred to as "ITO") or the like are extended in the vertical direction to the paper on the smoothing film 12, and an oriented film 9 of polyimide or the like is disposed above the transparent electrodes 8 so as to cover the transparent electrodes 8.

[0109] Also, a 1/4 wavelength plate 18, a lower polarization plate 14, and a reflecting polarizer 19, are disposed on the outer side of the lower substrate 2.

[0110] On the other hand, the upper substrate 3 is formed of glass or resin or the like, with stripe-shaped transparent electrode (common electrode) 7 formed of a transparent electroconductive film such as ITO or the like on the inner side of the upper substrate 3, extending in the direction orthogonal to the transparent electrodes 8 provided on the

lower substrate 2 (the sideways direction in the drawing), having an oriented film 15 of polyimide or the like disposed below the transparent electrode 7 so as to cover the transparent electrode 7.

[0111] Also, on the outer side of the upper substrate 3, a forward scattering plate 16, a phase difference plate 17, and an upper polarization plate 13 are layered and disposed in that order on the upper substrate 3.

[0112] Also, a reflecting plate 51 is disposed on the lower face side of the back-light 5 (the opposite side from the liquid crystal panel 1).

[0113] Next, the planar overlapping of the transflective layer 6 and the color filter 10 in the liquid crystal display device shown in Fig. 15 will be described.

[0114] The transflective layer 6 is formed of a metal film with high reflectivity such as aluminum or the like, and as shown in Fig. 16, is formed by opening the metal film in the form of windows, having, for each pixel, transmissive areas 6a for transmitting light emitted from the back-light 5 and incident light from the upper substrate 3 side, and a reflective area 6b for reflecting incident light from the upper substrate 3 side.

[0115] On the other hand, the color filter 10 is provided corresponding to each pixel making up the display area, with the red layer 11R and green layer 11G and blue layer 11B extending in the direction vertical to the paper so as to be orthogonal to the transparent electrode 7 provided on the upper substrate 3 described above, having pigment layers repeatedly arrayed in the order of the red layer 11R, green layer 11G, and blue layer 11B.

[0116] The pigment layers 11R, 11G, and 11B are provided on the entirety of the area overlapping the transmissive areas 6a of the transflective layer 6 in a planar manner, and an area excluding a part of an area overlapping the reflective area 6b in a planar manner by opening the pigment layers 11R, 11G, and 11B in window fashion, as shown in Fig. 16. Thus, the color filter 10 comprises a pigment layer formation area wherein the pigment layers 11R, 11G, and 11B are provided, and pigment layer non-formation areas 11D, 11E, and 11F which are a part of an area overlapping with the reflective area 6b in a planar manner but where the pigment layers 11R, 11G, and 11B are not provided. Also, with this liquid crystal display device, the area of the pigment layer formation area, i.e., the area of the pigment layers 11R, 11G, and 11B, is set such that the red layer 11R, blue layer 11B, and green layer 11G are smaller in that order.

[0117] As shown in Fig. 15, with such a liquid crystal display device, external light 30a cast into the liquid crystal display device from the upper substrate 3 side when in the reflective mode passes through the color filter 10, is reflected by the reflective area 6b of the transflective layer 6, passes through the color filter 10 again, and is emitted externally from the upper substrate 3 side. External light 30b cast into the liquid crystal display device from the upper substrate 3 side when in the reflective mode does not pass through the color filter 10 but is reflected by the reflective area 6b, and is emitted externally from the upper substrate 3 side. External light 30c cast into the liquid crystal display device from the upper substrate 3 side when in the reflective mode passes through the transmissive areas 6a, and accordingly does not become reflected light.

[0118] That is to say, in the reflected light, there is light 30a which passes through the pigment layers 11R, 11G, and 11B, and light 30b which passes through the pigment layer non-formation areas 11D, 11E, and 11F, wherein only the light 30a which has passed through the pigment layers 11R, 11G, and 11B is colored, and the light 30b which has passed through the pigment layer non-formation areas 11D, 11E, and 11F is not colored.

[0119] Accordingly, the light emitted externally from the upper substrate 3 side when in the reflective mode is the sum of the colored light 30a which has passed through the pigment layers 11R, 11G, and 11B and the uncolored light 30b which has passed through the pigment layer non-formation areas 11D, 11E, and 11F.

[0120] Also, the light 50a cast into the liquid crystal display device from the back-light 5 when in the transmissive mode passes through the transmissive areas 6a, passes through the pigment layers 11 of the color filter 10, and is colored. Also, the light 50b cast into the liquid crystal display device from the back-light 5 when in the transmissive mode is shielded by the transflective layer 6.

[0121] Accordingly, the light emitted externally from the upper substrate 3 side when in the transmissive mode becomes light 50a which has passed through the pigment layers 11 of the color filter 10 once and is colored.

[0122] With such a liquid crystal display device, there are pigment layer non-formation areas 11D, 11E, and 11F at a part of an area overlapping with the reflective area 6b in a planar manner, so as described above, the light obtained when in the reflective mode is the sum of the uncolored light 30b which has passed through the pigment layer non-formation areas 11D, 11E, and 11F and the colored light 30a which has passed through the pigment layers 11. On the other hand, the light obtained when in the transmissive mode is only the light 50a which passes through the pigment layer 11 and is colored.

[0123] Accordingly, the difference in concentration between the light obtained by passing through the color filter 10 twice when in the reflective mode and the light obtained by passing through the color filter 10 once when in the transmissive mode can be reduced.

[0124] Consequently, a color transflective liquid crystal display device with a bright highly visually recognizable display, for both the reflective mode and transmissive mode, can be realized.

[0125] Moreover, with the liquid crystal display device shown in Fig. 15, the pigment layer 11 is formed of the red layer 11R, green layer 11G, and blue layer 11B, with the area of the pigment layers 11R, 11G, and 11B being such that

the red layer 11R, blue layer 11B, and green layer 11G are smaller in that order, and the color properties of the color filter 10 are adjusted by changing the area of the pigment layers 11R, 11G, and 11B, so that the color reproduction can be improved even further, and a liquid crystal display device having even more excellent display quality can be realized.

[0126] Also, the liquid crystal display device shown in Fig. 15 has a transparent film 12 for smoothing the steps between the areas where the pigment layers 11R, 11G, and 11B are provided and the pigment layer non-formation areas 11D, 11E, and 11F, so adverse effects due to steps between the areas where the pigment layers 11R, 11G, and 11B are provided and the pigment layer non-formation areas 11D, 11E, and 11F can be avoided, thereby improving the reliability of the liquid crystal display device.

[0127] Also, the transflective layer fabricated with a thin metal film absorbs light in addition to reflecting and transmitting light, but with the liquid crystal display device shown in Fig. 15, the transflective layer 6 is opened in a window-like manner, thereby forming the transmissive areas 6a, so there is no absorbing of light, thereby enabling improving of the reflectivity and transmittance ratio.

<F: Fifth Embodiment: Liquid crystal display device>

[0128] With the fifth embodiment, the overall configuration of the liquid crystal display device is the same as the fourth embodiment shown in Fig. 15, and accordingly detailed description will be omitted.

[0129] Also, the point where the liquid crystal display device according to the fifth embodiment differs from the liquid crystal display device according to the fourth embodiment is only the form of the transflective layer and the color filter, so description of the transflective layer and the color filter will be given in detail with reference to Fig. 17.

[0130] Fig. 17 is a diagram illustrating only the transflective layer and the color filter and the transparent electrodes on the lower substrate in the liquid crystal display device according to the fifth embodiment, wherein Fig. 17(A) is a plan view for describing the overlapping of the transflective layer and the color filter, and Fig. 17(B) is a cross-sectional diagram following line C-C' shown in Fig. 17(A).

[0131] Note that in Fig. 17, the components held in common with the fourth embodiment are denoted with the same reference numerals.

[0132] As with the transparent electrodes 8 provided on the lower substrate 2, the transflective layer 61 is extended and provided in a stripe form in the direction vertical to the paper so as to be orthogonal to the transparent electrode 7 provided on the upper substrate 3, and provided with the same pitch as the transparent electrodes 8 provided on the lower substrate 2. Then, as shown in Fig. 17(B), the width of the pattern of the transparent electrodes 8 provided on the lower substrate 2 is formed so as to be greater than the width of the metal film pattern making up the transflective layer 61, so that band-shaped areas where the metal film making up the transflective layer 61 and the transparent electrodes 8 do not overlap in a parallel manner serve as transmissive areas 61a, and the entire area where the metal film is provided serves as a reflective area 61b.

[0133] On the other hand, as with the fourth embodiment, the color filter 101 is provided for each of the pixels making up the display area, with the red layer 111R and green layer 111G and blue layer 111B extending in the direction vertical to the paper so as to be orthogonal to the transparent electrode 7 provided on the upper substrate 3, having pigment layers 111 repeatedly arrayed in the order of the red layer 111R, green layer 111G, and blue layer 111B.

[0134] As shown in Fig. 17, the pigment layers 111R, 111G, and 111B, are provided on the entirety of the area overlapping the transmissive areas 61a of the transflective layer 61 in a planar manner, and an area excluding a part of an area overlapping the reflective area 61b of the transflective layer 61 in a planar manner by opening the pigment layers 111R, 111G, and 111B in stripe forms.

[0135] Accordingly, existing in the color filter 101 are a pigment layer formation area where the pigment layers 111R, 111G, and 111B are formed, and pigment layer non-formation areas 111D, 111E, and 111F which are a part of an area overlapping with the reflective area 61b in a planar manner where the pigment layers 111R, 111G, and 111B are not provided.

[0136] Also, with this liquid crystal display device, the area of the pigment formation area, i.e., the area of the pigment layers 111R, 111G, and 111B, is set such that the red layer 111R, blue layer 111B, and green layer 111G are smaller in that order, as with the fourth embodiment.

[0137] Such a liquid crystal display device also has pigment layer non-formation areas 111D, 111E, and 111F at a part of an area overlapping with the reflective area 61b of the transflective layer 61 in a planar manner, as with the fourth embodiment, so a part of the external light cast into the liquid crystal display device when in the reflective mode passes through the pigment layer non-formation areas 111D, 111E, and 111F, and the light obtained by passing trough the color filter 101 twice when in the reflective mode is the sum of the uncolored light which has passed through the pigment layer non-formation areas 111D, 111E, and 111F and the colored light which has passed through the pigment layers 111. On the other hand, the light which is cast in from the back-light 5 when in the transmissive mode and passes through the transmissive areas 61a all passes through the pigment layer 111, so light obtained by passing through the color filter 101 once when in the transmissive mode is all colored. Accordingly, the difference in concentration between

the light obtained by passing through the color filter twice when in the reflective mode and the light obtained by passing through the color filter once when in the transmissive mode can be reduced.

[0138] Consequently, a color transflective liquid crystal display device with similarly good colorization and high visual recognition, for both the reflective mode and transmissive mode, can be realized.

[0139] Moreover, with the liquid crystal display device according to the present embodiment as well, the pigment layer 111 is formed of the red layer 111R, green layer 111G, and blue layer 111B, with the area of the pigment layers 111R, 111G, and 111B being such that the red layer 111R, blue layer 111B, and green layer 111G are smaller in that order, and the color properties of the color filter 101 are adjusted by changing the area of the pigment layers 111R, 111G, and 111B, so that the color reproduction can be improved even further, and a liquid crystal display device having even more excellent display quality can be realized.

[0140] Also, with such a liquid crystal display device, with regard to the transflective layer 61, the width of the pattern of the transparent electrodes 8 provided on the lower substrate 2 is formed so as to be greater than the width of the metal film pattern making up the transflective layer 61, thereby forming band-shaped transmissive areas 61a and reflective areas 61b are formed, so irregularities in the longitudinal direction of the openings are reduced as compared to a transflective layer with window-like openings, and accordingly this is stable from the perspective of manufacturing.

<G: Sixth Embodiment: Liquid crystal display device>

[0141] Fig. 18 is a diagram illustrating an example of another liquid crystal display device according to the present invention, and is a partial cross-sectional view illustrating an example of a passive matrix transflective color liquid crystal display device wherein a color filter is provided on the inner side of the upper substrate. Also, Fig. 19 is a diagram illustrating only the transflective layer and color filter and shielding film of the liquid crystal display device shown in Fig. 18, wherein Fig. 19(A) is a plan view for describing the overlapping of the transflective layer and the color filter, and Fig. 19(B) is a cross-sectional view along B-B' shown in Fig. 19(A).

[0142] Note that in Fig. 18 and Fig. 19, the components held in common with the fourth embodiment are denoted with the same reference numerals, and accordingly detailed description thereof will be omitted.

[0143] The liquid crystal display device shown in Fig. 18 has a schematic configuration comprising a liquid crystal panel 100 and a back-light (illumination device) 5 disposed at the rear side of the liquid crystal panel 100 (at the outer side of the lower substrate 2).

[0144] Also, the liquid crystal panel 100 has a schematic configuration comprising a liquid crystal layer 4 sandwiched between the lower substrate 2 and upper substrate 3 disposed facing one another, as with the fourth embodiment.

[0145] The lower substrate 2 has formed on the inner side thereof a transflective layer 6 and an insulating film 23 in that order, with a stripe-shaped transparent electrode 8 (a common electrode here) formed of a transparent electro-conductive film such as ITO or the like extending sideways in the drawing upon the insulating film 23, and an oriented film 9 of polyimide or the like disposed above the transparent electrode 8 so as to cover the transparent electrode 8.

[0146] Also, a 1/4 wavelength plate 18, a lower polarization plate 14, and a reflecting polarizer 19, are disposed on the outer side of the lower substrate 2, as with the fourth embodiment.

[0147] On the other hand, a color filter 20 is layered on the inner side of the upper substrate 3, with a shielding film 42 of a black-colored resin material or the like provided between the pigment layers 21R, 21G, and 21B making up the color filter 20. Also, a transparent smoothing film 22 for smoothing the unevenness formed by the color filter 20 is layered below the color filter 20. Further, stripe-shaped transparent electrodes (segment electrodes here) 7 formed of a transparent electroconductive film such as ITO or the like are extended in a direction orthogonal to the transparent electrode 8 disposed on the lower substrate 2 (in the vertical direction to the paper) under the smoothing film 22, and an oriented film 15 is disposed below the transparent electrodes 7 so as to cover the transparent electrodes 7.

[0148] Also, a forward scattering plate 16, a phase difference plate 17, and an upper polarization plate 13 are layered and disposed in that order on the outer side of the upper substrate 3, as with the fourth embodiment.

[0149] Also, a reflecting plate 51 is disposed on the lower face side of the back-light 5 (the opposite side from the liquid crystal panel 1), as with the fourth embodiment.

[0150] Next, the planar overlapping of the transflective layer and the color filter in the liquid crystal display device shown in Fig. 18 will be described. With the liquid crystal display device shown in Fig. 18, the position where the liquid crystal display device according to the fourth embodiment shown in Fig. 15 and the color filter thereof is different, but the planar overlapping of the transflective layer and the color filter is the same as that in the fourth embodiment.

[0151] The transflective layer 6 the same as that in the fourth embodiment, and as shown in Fig. 19, is formed by opening metal film in the form of windows, having, for each pixel, transmissive areas 6a and a reflective area 6b.

[0152] On the other hand, the color filter 20 has the red layer 21R and green layer 21G and blue layer 21B extending in the direction vertical to the paper so as to be orthogonal to the transparent electrode 8 provided on the lower substrate 2, having pigment layers 21 repeatedly arrayed in the order of the red layer 21R, green layer 21G, and blue layer 21B.

[0153] As shown in Fig. 19, the pigment layers 21R, 21G, and 21B are provided on the entirety of the area overlapping

the transmissive areas 6a of the transflective layer 6 in a planar manner, and an area excluding a part of an area overlapping the reflective area 6b of the transflective layer 6 in a planar manner, by opening the pigment layers 21R, 21G, and 21B, in window fashion. Thus, the color filter 20 comprises a pigment layer formation area wherein the pigment layers 21 are provided, and pigment layer non-formation areas 21D, 21E, and 21F which are a part of an area overlapping with the reflective area 6b in a planar manner but where the pigment layers 21R, 21G, and 21B are not provided. Also, with this liquid crystal display device, the area of the pigment formation area, i.e., the area of the pigment layers 21R, 21G, and 21B, is set such that the red layer 21R, blue layer 21B, and green layer 21G are smaller in that order, as with the fourth embodiment.

[0154] As shown in Fig. 18, with such a liquid crystal display device as well, of the light which is emitted externally from the upper substrate 3 side in the reflective mode, there is light 30a which passes through the pigment layers 21R, 21G, and 21B, and light 30b which passes through the pigment layer non-formation areas 21D, 21E, and 21F, wherein only the light 30a which has passed through the pigment layers 21R, 21G, and 21B is colored, and the light 30b which has passed through the pigment layer non-formation areas 21D, 21E, and 21F is not colored. Accordingly, as with the fourth embodiment, with such a liquid crystal display device, the light emitted externally from the upper substrate 3 side when in the reflective mode is the sum of the uncolored light 30b and the colored light 30b.

[0155] On the other hand, the light externally emitted from the upper substrate 3 side in the transmissive mode also becomes colored light 50a which has passed through the pigment layers 21 of the color filter 20 once, as with the fourth embodiment.

[0156] Accordingly, with the liquid crystal display device according to the present embodiment as well, the difference in concentration between the light obtained by passing through the color filter 20 twice when in the reflective mode and the light obtained by passing through the color filter 20 once when in the transmissive mode can be reduced.

[0157] Consequently, a color transflective liquid crystal display device with good colorization and a highly visually recognizable display, for both the reflective mode and transmissive mode, can be realized.

[0158] Moreover, with the liquid crystal display device shown in Fig. 19, the pigment layer 21 is formed of the red layer 21R, green layer 21G, and blue layer 21B, with the area of the pigment layers 21R, 21G, and 21B being such that the red layer 21R, blue layer 21B, and green layer 21G are smaller in that order, and the color properties of the color filter 20 are adjusted by changing the area of the pigment layers 21R, 21G, and 21B, so that the color reproduction can be improved even further, and a liquid crystal display device having even more excellent display quality can be realized.

<H: Seventh Embodiment: Liquid crystal display device>

[0159] Fig. 20 is a diagram illustrating an example of another liquid crystal display device according to the present invention, and is a partial cross-sectional view illustrating an example of a passive matrix transflective liquid crystal display device wherein transparent electrodes are directly provided on the transflective layer. Also, Fig. 21 is a diagram illustrating only the transflective layer and color filter and transparent electrodes on the lower substrate, in the liquid crystal display device shown in Fig. 20, wherein Fig. 21(A) is a plan view for describing the overlapping of the transflective layer and the color filter, and Fig. 21(B) is a cross-sectional view along D-D' shown in Fig. 21(A).

[0160] Note that in Fig. 20 and Fig. 21, the components held in common with the fourth embodiment are denoted with the same reference numerals, and accordingly, detailed description will be omitted.

[0161] The liquid crystal display device shown in Fig. 20 has a schematic configuration comprising a liquid crystal panel 200 and a back-light (illumination device) 5 disposed at the rear side of the liquid crystal panel 200 (at the outer side of the lower substrate 2).

[0162] Also, the liquid crystal panel 200 has a schematic configuration comprising a liquid crystal layer 4 sandwiched between the lower substrate 2 and upper substrate 3 disposed facing one another, as with the fourth embodiment.

[0163] The lower substrate 2 has formed on the inner side thereof a transflective layer 62 formed of a metal film with high reflectance such as aluminum or the like, and stripe-shaped transparent electrodes 8 (segment electrodes here) disposed directly on the transflective layer 62 and formed of a transparent electroconductive film such as ITO or the like, both extending vertically in the drawing, and an oriented film 9 disposed above the transparent electrodes 8 so as to cover the transparent electrodes 8.

[0164] Also, a 1/4 wavelength plate 18, a lower polarization plate 14, and a reflecting polarizer 19, are disposed on the outer side of the lower substrate 2, as with the fourth embodiment.

[0165] On the other hand, a color filter 104 is layered on the inner side of the upper substrate 3, with a shielding film 43 provided between the pigment layers 114R, 114G, and 114B making up the color filter 104. Also, a transparent smoothing film 32 for smoothing the unevenness formed by the color filter 104 is layered below the color filter 104. Further, a stripe-shaped transparent electrode (a common electrode here) 7 formed of a transparent electroconductive film ITO or the like is extended in a direction orthogonal to the transparent electrodes 8 disposed on the lower substrate 2 (in the sideways direction to the paper) under the smoothing film 32, and an oriented film 15 is disposed below the

transparent electrode 7 so as to cover the transparent electrode 7.

[0166] Also, at the outer side of the upper substrate 3, a forward scattering plate 16, a phase difference plate 17, and an upper polarization plate 13 are layered and disposed in that order on the upper substrate 3, as with the fourth embodiment.

[0167] Also, a reflecting plate 51 is disposed on the lower face side of the back-light 5 (the opposite side from the liquid crystal panel 1), as with the fourth embodiment.

[0168] Next, the planar overlapping of the transflective layer and the color filter in the liquid crystal display device shown in Fig. 20 will be described.

[0169] The transflective layer 62, as with the fifth embodiment, is provided with the same pitch as the transparent electrodes 8 provided on the lower substrate 2, and as shown in Fig. 21(B), the width of the pattern of the transparent electrodes 8 provided on the lower substrate 2 is formed so as to be greater than the width of the metal film pattern making up the transflective layer 62, so that band-shaped areas where the metal film making up the transflective layer 62 and the transparent electrodes 8 do not overlap in a planar manner serve as transmissive areas 62a, and the entire area where the metal film is provided serves as a reflective area 62b.

[0170] On the other hand, the color filter 104 is provided corresponding to each of the pixels making up the display area as with the fourth embodiment, and has the red layer 114R and green layer 114G and blue layer 114B extending in the direction vertical to the paper so as to be orthogonal to the transparent electrode 7 provided on the upper substrate 3, having pigment layers 114 repeatedly arrayed in the order of the red layer 114R, green layer 114G, and blue layer 114B.

[0171] As shown in Fig. 21, the green layer 114G is provided on the entirety of the area overlapping the transmissive areas 62a of the transflective layer 62 in a planar manner, and an area excluding a part of an area overlapping the reflective area 62b of the transflective layer 62 in a planar manner by opening the green layer 114G in stripe fashion. Thus, the color filter 104 comprises a pigment layer formation area wherein the pigment layers 114R, 114G, and 114B are provided, and a pigment layer non-formation area 114E which is a part of an area overlapping with the reflective area 62b in a planar manner but where the green layer 114G is not provided. Also, with this liquid crystal display device, the area of the pigment formation area, i.e., the area of the pigment layers 114R, 114G, and 114B, is set such that the red layer 114R, blue layer 114B, and green layer 114G are smaller in that order.

[0172] As shown in Fig. 20, with such a liquid crystal display device as well, of the light which is emitted externally from the upper substrate 3 side in the reflective mode, there is light 30a which passes through the pigment layers 114R, 114G, and 114B, and light 30b which passes through the pigment layer non-formation area 114E, wherein only the light 30a which has passed through the pigment layers 114R, 114G, and 114B is colored, and the light 30b which has passed through the pigment layer non-formation area 114E is not colored. Accordingly, with such a liquid crystal display device as well, the light emitted externally from the upper substrate 3 side when in the reflective mode is the sum of the uncolored light 30b and the colored light 30b.

[0173] On the other hand, the light externally emitted from the upper substrate 3 side in the transmissive mode also becomes colored light 50a which has passed through the pigment layers 114 of the color filter 104 once, as with the fourth embodiment.

[0174] Accordingly, with the liquid crystal display device according to the present embodiment as well, the difference in concentration between the light obtained by passing through the color filter 104 twice when in the reflective mode and the light obtained by passing through the color filter 104 once when in the transmissive mode can be reduced.

[0175] Consequently, a color transflective liquid crystal display device with good colorization and a highly visually recognizable display, for both the reflective mode and transmissive mode, can be realized.

[0176] Moreover, with the liquid crystal display device according to the present embodiment, the pigment layer 114 is formed of the red layer 114R, green layer 114G, and blue layer 114B, with the area of the pigment layers 114R, 114G, and 114B being such that the green layer 114G is smaller than the red layer 114R and blue layer 114B, and the color properties of the color filter 104 are adjusted by changing the area of the green layer 114G, so that the color reproduction can be improved even further, and a liquid crystal display device having even more excellent display quality can be realized.

[0177] Further, the pigment layer non-formation area 114E is dependent on only the green layer 114G which contributes to colorization of green which is the most visually effective color, so excellent colorization can be obtained, and deterioration of reflectance due to providing the pigment layer non-formation area 114E can be reduced.

[0178] Further, with the liquid crystal display device according to the present embodiment, the transparent electrodes 8 formed of a transparent electroconductive film are directly disposed on the transflective layer 62 formed of metal film, so the resistance value of the transparent electrodes 8 can be reduced thereby reducing chrominance non-uniformity in display.

<I: Eighth Embodiment: Liquid crystal display device>

[0179] With the eighth embodiment, the overall configuration of the liquid crystal display device is the same as the fourth embodiment shown in Fig. 15, and accordingly detailed description will be omitted.

[0180] Also, the liquid crystal display device according to the eighth embodiment has different area for the transmissive areas of the sub-pixels as with the above-described first embodiment, and also is formed so that the area of the pigment layer non-formation areas in the pigment layer differ as with the above-described fourth embodiment. Accordingly, detailed description of the configurations which are the same as the liquid crystal display device according to the first embodiment and the liquid crystal display device according to the fourth embodiment will be omitted, and description of the forms of the transflective layer and color filter which are the characteristic parts of the liquid crystal display device according to the eighth embodiment will be given in detail, with reference to the drawings.

[0181] Note that with the eighth embodiment, description will be made regarding an example of a case of using illumination light wherein the luminance of wavelengths corresponding to green is stronger that the luminance of other wavelengths, and wherein the luminance of wavelengths corresponding to blue is weaker that the luminance of other wavelengths.

[0182] Fig. 32 is a diagram illustrating the transflective layer and color filter of the liquid crystal display device according to the eighth embodiment, and is a diagram corresponding to Fig. 16(A) described with the fourth embodiment.

[0183] In Fig. 32, reference numeral 703 denotes a transflective layer. The transflective layer 703 has, for each pixel, transmissive areas 701 formed by opening the metal film in window fashion for light emitted from the back-light 5 or incident light from the upper substrate 3 to pass through, and reflective area 702 (hatched diagonally upwards toward the right in Fig. 32) for reflecting incident light from the upper substrate 3, as with the fourth embodiment.

[0184] However, unlike the fourth embodiment the present embodiment, as shown in Fig. 32, the transflective layer 703 is such that the area of the opening portions corresponding to each of the sub-pixels 751R, 751G, and 751B, making up each pixel 751, that is to say, the area of the transmissive areas 701R, 701G, and 701B, making up the transflective layers 703R, 703G, and 703B, and the area of the reflective areas 702R, 702G, and 702B, are at area ratios according to the spectral properties of the illumination light emitted from the illumination device 5.

[0185] On the other hand, as with the fourth embodiment, the color filter is provided for each of the pixels making up the display area, with the red layer 711R and green layer 711G and blue layer 711B extending so as to be orthogonal to the transparent electrode 7 provided on the upper substrate 3, having pigment layers 711 repeatedly arrayed in the order of the red layer 711R, green layer 711G, and blue layer 711B.

[0186] As shown in Fig. 32, the pigment layers 711R, 711G, and 711B, are provided on the entirety of the area overlapping the transmissive areas 701R, 701G, and 701B of the transflective layers 703R, 703G, and 703B in a planar manner, and an area excluding a part of an area overlapping the reflective areas 702R, 702G, and 702B in a planar manner by opening the pigment layers 711R, 711G, and 711B in window forms. Accordingly, existing in the color filter are a pigment layer formation area where the pigment layers 711R, 711G, and 711B are formed, and pigment layer non-formation areas 711D, 711E, and 711F which are a part of an area overlapping with the reflective areas 702R, 702G, and 702B in a planar manner where the pigment layers 711R, 711G, and 711B are not provided.

[0187] With the present embodiment, with regard to the sub-pixel 751G where the green layer (green color filter) 711G is formed, the area of the transmissive area 701G corresponding thereto is smaller in comparison to the sub-pixels 751R and 751B corresponding to the other colors. Conversely, with regard to the sub-pixel 751B where the blue layer (blue color filter) 711B is formed, the area of the transmissive area 701B corresponding thereto is larger in comparison to the sub-pixels 751R and 751G corresponding to the other colors.

[0188] Also, with this liquid crystal display device, the area of the pigment layer formation area, i.e., the area of the pigment layers 711R, 711G, and 711B, is set such that the blue layer 711B, red layer 711R, and green layer 711G are smaller in that order.

[0189] With such a liquid crystal display device, the display colors and brightness are adjusted by performing both of the following first adjustment and second adjustment.

"First Adjustment"

[0190] The brightness is adjusted such that transmittance ratio sufficient for obtaining bright light when in the transmissive mode, by changing the ratio of the transmissive areas 701R, 701G, and 701B, and the reflective areas 702R, 702G, and 702B.

[0191] Also, the sub-pixel 751G where the green layer 711G is formed is made to be smaller in comparison with the other sub-pixels 751R and 751B, and the sub-pixel 751B where the blue layer 711B is formed is made to be larger in comparison with the other sub-pixels 751R and 751G, thereby changing the ratio of the transmissive areas 701R, 701G, and 701B, and the reflective areas 702R, 702G, and 702B. Thus, there is sufficient light of the wavelengths corresponding to the red light and blue light which have comparatively low luminance in the illumination light passing

through the transflective layer 703, while transmittance of light with the wavelength corresponding to green which have comparatively high luminance through the transflective layer 703 is restricted, thereby adjusting the color display.

"Second Adjustment"

[0192] The brightness is adjusted such that transmittance ratio sufficient for obtaining bright light when in the reflective mode, by changing the ratio of the area of the pigment layer formation area which is the area of the pigment layers 711R, 711G, and 711B, and the area of the pigment layer non-formation areas 711D, 711E, and 711F.

[0193] Also, the area of the pigment layers 711R, 711G, and 711B, is set such that the blue layer 711B, red layer 711R, and green layer 711G are smaller in that order, and the ratio of the area of the pigment layer formation area which is the area of the pigment layers 711R, 711G, and 711B, as to the area of the pigment layer non-formation areas 711D, 711E, and 711F, is changed. Thus, the color properties of the color filter are adjusted, and display color is adjusted.

[0194] Note that color display when in the reflective mode is changed in the first adjustment by changing the area of the reflective areas 702R, 702G, and 702B accompanying changing the ratio of the transmissive areas 701R, 701G, and 701B and the reflective areas 702R, 702G, and 702B, even in the event that the display color in the reflective mode has changed due to the first adjustment, change in the display color when in the reflective mode due to the first adjustment can be prevented from causing problems in the display color in the actual reflective mode by performing the second adjustment taking into consideration the change in display color by the first adjustment.

[0195] With the liquid crystal display device according to the present embodiment, both the first adjustment which is carried out by changing the ratio of the transmissive areas 701R, 701G, and 701B, and the reflective areas 702R, 702G, and 702B, and the second adjustment which is carried out by changing the ratio of the area of the pigment layer formation area and the area of the pigment layer non-formation areas 711D, 711E, and 711F, are performed, so in the event that the transmissive areas 701R, 701G, and 701B are enlarged in the first adjustment so that bright display can be obtained in the transmissive mode with improved transmittance ratio and the reflective areas 702R, 702G, and 702B become small, reducing the area of the pigment layer non-formation areas 711D, 711E, and 711F in the second adjustment allows transmittance ratio sufficient for obtaining bright light when in the reflective mode to be obtained. Accordingly, there is no problem of the display when in the reflective mode becoming dark even in the event that the transmissive areas 701R, 701G, and 701B are enlarged so that bright display can be obtained in the transmissive mode.

[0196] Thus, according to the above-described liquid crystal display device, brightness can be effectively adjusted, and a bright display can be made both in the reflective mode and the transmissive mode.

[0197] With the liquid crystal display device according to the present embodiment, both the first adjustment which is carried out by changing the ratio of the transmissive areas 701R, 701G, and 701B, and the reflective areas 702R, 702G, and 702B, and the second adjustment which is carried out by changing the ratio of the area of the pigment layer formation area and the area of the pigment layer non-formation areas 711D, 711E, and 711F, are performed, so display color can be effectively adjusted, and extremely excellent color reproduction can be obtained.

[0198] Specifically, with the liquid crystal display device according to the present embodiment, the effects which irregularities in spectral properties of the illumination light have on the observed light can be suppressed, and event in the event that transmissive display is performed using illumination light wherein the luminance of wavelengths corresponding to the green light is greater than the luminance of the other wavelengths, and wherein the luminance of wavelengths corresponding to the blue light is smaller than the luminance of the other wavelengths, situations wherein the image visually recognized by the observer is colored, can be avoided. That is to say, as with the first embodiment, the non-uniformity in the spectral properties of the illumination light are compensated, thereby realizing good color reproduction.

[0199] Further, whereas the first embodiment is only adjustment of the display color and brightness equivalent to the first adjustment in the present embodiment, and the fourth embodiment is only adjustment of the display color and brightness equivalent to the second adjustment in the present embodiment, both the first adjustment and second adjustment are performed with the liquid crystal display device according to the present embodiment, so color reproduction can be improved even further, and a liquid crystal display device having even more excellent display quality can be realized.

[0200] Moreover, with this liquid crystal display device, pigment layer non-formation areas 711D, 711E, and 711F are formed at a part of the area overlapping the reflective areas 702R, 702G, and 702B of the transflective layers 703R, 703G, and 703B in a planar manner, so part of the external light cast into the liquid crystal display device when in the reflective mode passes through the pigment layer non-formation areas 711D, 711E, and 711F, and the light obtained by passing trough the color filter twice when in the reflective mode is the sum of the uncolored light which has passed through the pigment layer non-formation areas 711D, 711E, and 711F and the colored light which has passed through the pigment layers 711. On the other hand, the light which is cast in from the back-light 5 when in the transmissive mode and passes through the transmissive areas 701R, 701G, and 701B, all passes through the pigment layer 711, so light obtained by passing through the color filter once when in the transmissive mode is all colored. Accordingly, the

difference in concentration between the light obtained by passing through the color filter twice when in the reflective mode and the light obtained by passing through the color filter once when in the transmissive mode can be reduced.

[0201] Consequently, as with the fourth embodiment, a color transflective liquid crystal display device capable of display with similarly good colorization and high visual recognition, for both the reflective mode and transmissive mode, can be realized.

<J: Ninth Embodiment: Liquid crystal display device>

[0202] With the ninth embodiment, the overall configuration of the liquid crystal display device is the same as the fifth embodiment shown in Fig. 17, and accordingly detailed description will be omitted.

[0203] Also, the liquid crystal display device according to the ninth embodiment has different area for the transmissive areas of the sub-pixels and also is formed so that the area of the pigment layer non-formation areas in the pigment layers differ, as with the above-described eighth embodiment. Accordingly, the liquid crystal display device according to the ninth embodiment differs from the liquid crystal display device according to the eighth embodiment only regarding the forms of the transflective layer and color filter. Accordingly, the transflective layer and color filter will be described in detail, with reference to the drawings.

[0204] Fig. 33 is a diagram illustrating the transflective layer and color filter of the liquid crystal display device according to the ninth embodiment, and is a diagram corresponding to Fig. 17(A) described with the fourth embodiment.

[0205] In Fig. 33, reference numeral 803 denotes a transflective layer. As with the fifth embodiment, the transflective layer 803 is extended and provided in a stripe form in the direction vertical to the paper so as to be orthogonal to the transparent electrode 7 provided on the upper substrate 3, and provided with the same pitch as the transparent electrodes 8 provided on the lower substrate 2. Then, as shown in Fig. 33, the width of the pattern of the transparent electrodes 8 provided on the lower substrate 2 is formed so as to be greater than the width of the metal film pattern making up the transflective layer 803, so that band-shaped areas where the metal film making up the transflective layer 803 and the transparent electrodes 8 do not overlap in a planar manner serve as transmissive areas 801, and the entire area where the metal film is provided serves as a reflective area 802 (hatched diagonally upwards toward the right in Fig. 33).

[0206] However, unlike the fifth embodiment, with the present embodiment, as shown in Fig. 33, the transflective layer 803 is such that the areas following the edges of the sub-pixels 851R, 851G, and 851B, making up each pixel 851, that is to say, the area of the transmissive areas 801R, 801G, and 801B, making up the transflective layers 803R, 803G, and 803B, and the area of the reflective areas 802R, 802G, and 802B, are at area ratios according to the spectral properties of the illumination light emitted from the illumination device 5.

[0207] On the other hand, as with the fifth embodiment, the color filter is provided for each of the pixels making up the display area, with the red layer 811R and green layer 811G and blue layer 811B extending so as to be orthogonal to the transparent electrode 7 provided on the upper substrate 3, having pigment layers 811 repeatedly arrayed in the order of the red layer 811R, green layer 811G, and blue layer 811B.

[0208] As shown in Fig. 33, the pigment layers 811R, 811G, and 811B, are provided on the entirety of the area overlapping the transmissive areas 801R, 801G, and 801B of the transflective layers 803R, 803G, and 803B in a planar manner, and an area excluding a part of an area overlapping the reflective areas 802R, 802G, and 802B of the transflective layers 803R, 803G, and 803B in a planar manner by opening the pigment layers 811R, 811G, and 811B in stripe forms.

[0209] Accordingly, existing in the color filter are a pigment layer formation area where the pigment layers 811R, 811G, and 811B are formed, and pigment layer non-formation areas 811D, 811E, and 811F which are a part of an area overlapping with the reflective areas 802R, 802G, and 802B in a planar manner where the pigment layers 811R, 811G, and 811B are not provided.

[0210] With the present embodiment also, with regard to the sub-pixel 851G where the green layer (green color filter) 811G is formed, the area of the transmissive area 801G corresponding thereto is smaller in comparison to the sub-pixels 851R and 851B corresponding to the other colors, as with the eighth embodiment. Conversely, with regard to the sub-pixel 851B where the blue layer (blue color filter) 811B is formed, the area of the transmissive area 801B corresponding thereto is greater in comparison to the sub-pixels 851R and 851G corresponding to the other colors.

[0211] Also, with this liquid crystal display device, the area of the pigment formation area, i.e., the area of the pigment layers 811R, 811G, and 811B, is set such that the blue layer 811B, red layer 811R, and green layer 811G are smaller in that order, as with the eighth embodiment.

[0212] With such a liquid crystal display device as well, the display colors and brightness can be adjusted by changing the ratio of the transmissive areas 801R, 801G, and 801B, and the reflective areas 802R, 802G, and 802B, and the display colors and brightness can be adjusted by changing the ratio of the area of the pigment layer formation area and the area of the pigment layer non-formation areas 811D, 811E, and 811F. Accordingly, display color and brightness can be effectively adjusted.

[0213] Consequently, as with the eighth embodiment, a liquid crystal display device capable of similarly bright display for both the reflective mode and transmissive mode, and extremely excellent color reproduction, can be realized.

[0214] Further, with this liquid crystal display device as well, pigment layer non-formation areas 811D, 811E, and 811F are formed, so the difference in concentration between the light obtained by passing through the color filter twice when in the reflective mode and the light obtained by passing through the color filter once when in the transmissive mode can be reduced, and a color transflective liquid crystal display device capable of display with similarly good colorization and high visual recognition, for both the reflective mode and transmissive mode, can be realized.

[0215] Note that the liquid crystal display device according to the present invention is not restricted to the above-described embodiments, but rather may be arranged wherein, for example the transflective layer is formed of aluminum, and the pigment layer includes a blue layer and red layer, wherein the area of the pigment layer formation area is set such that the blue layer is smaller in comparison with the red layer.

[0216] With such a liquid crystal display device, the area of the pigment layer formation area is set such that the blue layer is smaller in comparison with the red layer, so even in the event that the light reflected by the transflective layer is colored blue due to the transflective layer being formed of aluminum, this can be corrected by passing through the color filter twice.

[0217] Accordingly, a liquid crystal display device having excellent color reproduction and high display quality can be realized.

[0218] Also, an arrangement may be made wherein the transflective layer is formed of silver, and the pigment layer includes a red layer and blue layer, wherein the area of the pigment layer formation area is set such that the red layer is smaller in comparison with the blue layer.

[0219] With such a liquid crystal display device, the area of the pigment layer formation area is set such that the red layer is smaller in comparison with the blue layer, so even in the event that the light reflected by the transflective layer is colored yellow due to the transflective layer being formed of silver, this can be corrected by passing through the color filter twice. Accordingly, a liquid crystal display device having excellent color reproduction and high display quality can be realized.

[0220] Also, with the liquid crystal display device according to the present invention, the smoothing film may be formed so as to cover over the color filter as in the example shown in the above-described embodiments, but anything that will smooth the unevenness formed by the color filter is sufficient, and thus may be formed only on the pigment layer non-formation area of the color filter, for example. With an arrangement wherein the smoothing film is formed only on the pigment layer non-formation area of the color filter, and an overcoat layer is provided over the smoothing film, the thickness of the overcoat layer can be made thinner as compared to arrangements wherein a smoothing film is not formed but rather an overcoat layer is provided. Also, an arrangement may be made wherein, for example, an overcoat layer is formed without forming a smoothing layer, wherein the unevenness formed by the color filter is smoothed by the overcoat layer, so that the overcoat layer also serves as a smoothing film.

[0221] Also, smoothing may be performed by embedding a smoothing film in the pigment layer non-formation area by forming a smoothing film, as with the example described in the above-described embodiment, but smoothing may be performed by forming a transparent layer separate from the smoothing film and embedding the pigment layer non-formation area, and then forming a smoothing film over the transparent layer and the pigment layer formation area.

[0222] Also, the transflective layer refers to an article having reflecting functions provided with a transmitting portions, and needs not be a simple reflective layer. That is to say, this may be a reflective polarizer having polarizing functions. Examples of reflective polarizers include circular polarization plates using cholesteric liquid crystal, beam-splitter linear polarization plates using angle-of-polarization, wire grid linear polarizers wherein multiple slits around 60 nm are formed in a reflective layer, and so forth.

[0223] Also, though passive matrix liquid crystal display devices can be given as examples of liquid crystal display devices to which the present invention can be applied, as with the above-described embodiments, the present invention is also applicable to active matrix liquid crystal display devices using thin film diodes (TFD), thin film transistors (TFT), and so forth, as switching devices.

(Electronic Equipment)

[0224] Next, description will be given regarding electronic equipment comprising the liquid crystal display device according to the above embodiments.

[0225] First, an example wherein the above-described liquid crystal display device is applied to the display unit of a cellular telephone will be described. Fig. 22 is a perspective view illustrating the configuration of this cellular telephone. As shown in the figure, the cellular telephone 1032 comprises multiple operating buttons 1321, an earpiece 1322, a mouthpiece 1323, and along with these, a display unit 1324 using the liquid crystal display device according to the present invention (only the first substrate 3 is shown in Fig. 22).

[0226] Fig. 23 is a perspective view illustrating an example of a wristwatch-type electronic device.

[0227] In Fig. 23, reference numeral 1100 denotes the main unit of the watch, and reference numeral 1101 denotes the liquid crystal display unit using the liquid crystal display device.

[0228] Fig. 24 is a perspective view illustrating an example of a portable information processing device such as a word processor, mobile personal computer, or the like.

[0229] In Fig. 24, reference numeral 1200 denotes the information processing device, reference numeral 1202 denotes an input unit such as a keyboard, reference numeral 1204 denotes the main unit of the information processing device, and reference numeral 1206 denotes the liquid crystal display unit using the liquid crystal display device.

[0230] Now, in addition to the cellular telephone shown in Fig. 22, the wristwatch-type electronic device shown in Fig. 23, and the personal computer shown in Fig. 24, examples of electronic equipment that can be given include liquid crystal televisions, viewfinder or monitor-viewed video cassette recorders, car navigation devices, pagers, palmtops, calculators, word processors, workstations, video phones, POS terminals, equipment having touch panels, and so forth.

[0231] As described above, with the liquid crystal display device according to the present invention, irregularities in spectral properties of the illumination light from the illumination device can be compensated and high color reproduction can be realized, which can be used to form electronic equipment comprising a liquid crystal display device with similarly good colorization and high visual recognition for both the reflective mode and transmissive mode, and accordingly this is particularly suitable for electronic equipment regarding which high-quality display is required.

[Embodiments]

[0232] Next, the advantages of the present invention will be made clear through embodiments, but the present invention is not restricted to the following embodiments. Also, the reflective film in the test example 1 through the test example 4 is a silver alloy colored yellow.

"Test example 1"

[0233] A liquid crystal display device according to the fifth embodiment shown in Fig. 17 was fabricated, the area ratio of the transmissive area and the reflective area was set at 17 : 19, and the pigment layer non-formation areas 111D, 111E, and 111F which are areas where the pigment layers 111R, 111G, and 111B, are not formed, are further set such that the area ratio thereof was red layer 111D : green layer 111E : blue layer 111F = 4 : 14 : 6.

"Test example 2"

[0234] As shown in Fig. 25, a liquid crystal display device was fabricated in the same manner as the liquid crystal display device according to the fifth embodiment shown in Fig. 17, except that the area ratio of the transmissive area and the reflective area was set at 17 : 19, and the pigment layer non-formation areas 112D, 112E, and 112F in the color filter 102 which are areas where the pigment layers 112R, 112G, and 112B, are not formed, are further set such that the area ratio thereof was red layer 112D : green layer 112E : blue layer 112F = 1 : 1 : 1.

"Test example 3"

[0235] As shown in Fig. 26, a liquid crystal display device was fabricated in the same manner as the liquid crystal display device according to the fifth embodiment shown in Fig. 17, except that the area ratio of the transmissive area and the reflective area was set at 11 : 25, and that there are no pigment layer non-formation areas in the color filter 103 which are areas where the pigment layers 113R, 113G, and 113B, are not formed, and that the color properties of the color filter were optimized (he color purity was lowered) to give priority to the display when in the reflective mode.

[0236] Now, with regard to the above test example 1 through test example 3, the test example 1 is an embodiment of the present invention, and test example 2 and test example 3 are comparative examples.

[0237] The light obtained when in the reflective mode and when in the transmissive mode was measured regarding the liquid crystal display devices according to test example 1 through test example 3 thus manufactured.

[0238] The results thereof are shown in Table 1, and Fig. 27 through Fig. 30.

[0239] Fig. 27 is a diagram illustrating the results of measuring the light emitted from the liquid crystal display device according to the test example 1, wherein Fig. 27(A) is a chromaticity diagram of the light obtained in the reflective mode, and 27(B) is a chromaticity diagram of the light obtained in the transmissive mode. Also, Fig. 28 is a diagram illustrating the results of measuring the light emitted from the liquid crystal display device according to the test example 2, wherein Fig. 28(A) is a chromaticity diagram of the light obtained in the reflective mode, and 28(B) is a chromaticity diagram of the light obtained in the transmissive mode. Also, Fig. 29 is a diagram illustrating the results of measuring the light emitted from the liquid crystal display device according to the test example 3, wherein Fig. 29(A) is a chromaticity diagram of the light obtained in the reflective mode, and 29(B) is a chromaticity diagram of the light obtained in

the transmissive mode.

[Table 1]

Mode	Reflective mode		Transmissive mode	
Properties	White display reflectivity	Color range area	White display reflectivity	Color range area
Test Example 1	26.3%	1.73×10^{-2}	2.3%	1.50×10^{-2}
Test Example 2	26.2%	1.55×10^{-2}	2.3%	1.50×10^{-2}
Test Example 3	34.1%	1.35×10^{-2}	2.1%	0.50×10^{-2}

[0240] Here, the term "color range area" means the area of a triangle formed by connecting the three points of the x, y coordinates of the red, green, and blue display colors on a CIE chromaticity diagram.

[0241] The liquid crystal display device according to the test example 3 which is a comparative example has a narrow color range area for both the light obtained in the reflective mode and the light obtained in the transmissive mode, as can be seen from Table 1, Fig. 29, and Fig. 30.

[0242] Also, the liquid crystal display device according to the test example 2 which is a comparative example, has a color range area wider in comparison with the liquid crystal display device according to the test example 3 for both the light obtained in the reflective mode and the light obtained in the transmissive mode, as can be seen from Table 1, Fig. 28, and Fig. 29. Moreover, there is sufficient white display reflectivity. However, with the light obtained in the reflective mode, the red display is purplish.

[0243] In comparison, the liquid crystal display device according to the test example 1, which is an embodiment of the present invention, has a color range area wider in comparison with the liquid crystal display device according to the test example 3 for both the light obtained in the reflective mode and the light obtained in the transmissive mode, as can be seen from Table 1, Fig. 27, and Fig. 28, and has sufficient white display reflectivity.

[0244] Further, the color range area for the light obtained in the reflective mode is also wider in comparison with the liquid crystal display device according to the test example 2. Moreover, as with the liquid crystal display device according to the test example 2, the color purity of the red display and blue display increases in the light obtained in the reflective mode.

[0245] Accordingly, it was confirmed that with the liquid crystal display device according to the test example 1 which is an embodiment of the present invention, there is little difference in concentration in color between the light obtained in the reflective mode and the light obtained in the transmissive mode, color reproduction is excellent, and there is sufficient white display reflectivity.

[0246] Thus, it is clear that in comparison with the liquid crystal display devices according to the test example 2 and test example 3 which are comparative examples, the liquid crystal display device according to the test example 1 which is an embodiment of the present invention has good colorization in both the reflective mode and the transmissive mode, and that display with high visual recognition can be made.

"Test example 4"

[0247] A liquid crystal display device according to a seventh embodiment shown in Fig. 20 and Fig. 21 was made, with the area ratio of the transmissive area and the reflective area at 17 : 19, and further the ratio of the area where the green layer 114G is formed and the pigment layer non-formation area 111E where the green layer 114G is not formed was set at 7 : 1, using a color filter having the spectral properties shown in Fig. 31 as the color filter. That is, in comparison to the liquid crystal display device according to the test example 1, the color purity of the green and red color filters is increased, and instead the color purity of the blue color filter is lowered, thereby raising the transmittance ratio.

[0248] Note that the above test example 4 is an embodiment of the present invention.

[0249] The light obtained when in the reflective mode and when in the transmissive mode was measured regarding liquid crystal display device according to the test example 4 thus manufactured, in the same manner as with the liquid crystal display device according to the test example 1.

[0250] The results thereof are shown in Table 2 and Fig. 30.

[0251] Fig. 30 is a diagram illustrating the results of measuring the light emitted from the liquid crystal display device according to the test example 4, wherein Fig. 30(A) is a chromaticity diagram of the light obtained in the reflective mode, and Fig. 30(B) is a chromaticity diagram of the light obtained in the transmissive mode.

[Table 2]

Mode	Reflective mode		Transmissive mode	
Properties	White display reflectivity	Color range area	White display reflectivity	Color range area
Test Example 4	26.0%	2.62×10^{-2}	2.2%	2.65×10^{-2}

[0252] As can be seen in Table 2 and Fig. 30, with the liquid crystal display device according to the test example 4, though the white display reflectivity and transmittance ratio did not change much in comparison to the liquid crystal display device according to the test example 1, the color purity of green increased, and the color range area of the light obtained in the reflective mode and the light obtained in the transmissive mode was also improved a great deal.

[0253] Accordingly, providing a pigment layer non-formation area 114E only for the green layer 114G which contributes to colorization of green which is the most visually effective color allows excellent colorization can be obtained, and deterioration of white display reflectivity due to providing the pigment layer non-formation area 114E can be reduced.

[0254] Also, lowering the color purity of the blue color filter to raise the transmittance ratio, and providing the pigment layer non-formation area 114E only for the green layer 114G, improved the yellow coloring owing to the reflective layer in the reflective mode being silver.

"Test Example 5 through Test Example 8"

[0255] Liquid crystal display devices were fabricated, using the areas shown in Table 3 as the transmissive area, the pigment layer formation area which is the area of the pigment layers, and the pigment layer non-formation area.

[0256] Note that of the above test example 5 through test example 8, test example 5 through test example 7 are embodiments of the present invention, and test example 8 is a conventional example.

[0257] Also, an example of the dimensions of the components for fabricating the liquid crystal display device according to the test example 7 is shown in Fig. 33. The units of length of the parts shown in Fig. 33 are in μm, with the sub-pixel pitch at 237 × 79 (μm), and the sub-pixel area at 14784 μm^2.

[Table 3]

		Test example 8	Test example 5	Test example 6	Test example 7
Area of transmissive area (μm^2)	Red	5824	6496	6496	6272
	Green	5824	4928	4928	4928
	Blue	5824	6496	6496	6270
Area of pigment layer formation area (μm^2)	Red	8960	8288	7748	7072
	Green	8960	6796	6256	4456
	Blue	8960	8288	8288	7344
Area of pigment layer non-formation area (μm^2)	Red	0	0	540	1440
	Green	0	3060	3600	5400
	Blue	0	0	0	720
Reflectivity (%)		17.1	20.0	21.2	25.1
White display in reflective mode	x	0.306	0.314	0.313	0.319
	y	0.335	0.327	0.325	0.324
Reflectivity (%)		3.0	3.0	3.0	3.0
White display in transmissive mode	x	0.312	0.311	0.311	0.310
	y	0.339	0.324	0.324	0.319

[0258] The white display x, y coordinates on the CIE chromaticity diagram in the reflective mode and the transmissive mode, the reflectivity, and the transmittance ratio, were measured for the liquid crystal display devices according to test example 5 through test example 8 thus fabricated.

[0259] The results thereof are shown in Table 3.

[0260] With the liquid crystal display device according to the test example 8, it can be understood that the white display when in the reflective mode and the white display when in the transmissive mode is greenish. Also, it can be understood that the reflectivity is low, and that the display in the reflective mode is dark.

[0261] In comparison, with the test example 5, in the state of maintaining the transmittance ratio in the test example 8, the width of the pattern of the metal film making up the transflective layer was adjusted to make the area of the transmissive area for the green smaller, and to make the area of the transmissive area for red and the transmissive area for blue larger, and also a green pigment layer non-formation area was provided.

[0262] Consequently, with the test example 5, as shown in Table 3, the reflectivity improved in comparison with the test example 8, the greenness of the white display in the reflective mode and the transmissive mode was improved, coming closer to the ideal white display color coordinates (x = 0.310, y = 0.316) on the CIE chromaticity diagram.

[0263] Also, with the test example 6, in the state of maintaining the transmittance ratio in the test example 8 and the area of the transmissive area in the test example 5, the green pigment layer non-formation area was enlarged, and also a red pigment layer non-formation area was provided.

[0264] Consequently, with the test example 6, as shown in Table 3, the reflectivity improved even more in comparison with the test example 5, the greenness of the white display in the reflective mode was improved even further, coming even closer to the ideal white display color coordinates.

[0265] Also, with the test example 7, in the state of maintaining the transmittance ratio in the test example 8 and the area of the green transmissive area in the test example 5 and the test example 6, the green pigment layer non-formation area was enlarged even further while reducing the area of the red transmissive area and enlarging the area of the blue transmissive area, the red pigment layer non-formation area was enlarged, and a blue pigment layer non-formation area was provided.

[0266] Consequently, with the test example 7, as shown in Table 3, the reflectivity improved even more in comparison with the test example 6 though the white display in the transmissive mode did not change much, coming even closer to the ideal white display color coordinates for white display in the transmissive mode.

[0267] It was thus confirmed from the test example 5 through test example 8 that securing transmittance ratio whereby a bright display can be obtained in the transmissive mode while enlarging the area of the pigment layer non-formation area allows sufficient reflectivity for a bright display in the reflective mode to be obtained, and that a liquid crystal display device capable of bright display in both the reflective mode and transmissive mode can be obtained.

[0268] Also, it was confirmed that a liquid crystal display device capable of display with excellent color reproduction in both the reflective mode and transmissive mode can be obtained, by adjusting the area of the transmissive area and the area of the pigment layer non-formation area (pigment layer formation area).

"Test Example 9"

[0269] A liquid crystal display device according to an eight embodiment shown in Fig. 32 was fabricated wherein the area of the transmissive areas 701R, 701G, and 701B, the pigment layer formation area which is the pigment layers 711R, 711G, and 711B, and the pigment layer non-formation areas 711D, 711E, and 711F are the same area as the seventh embodiment shown in Table 3.

[0270] Note that the test example 9 is an embodiment of the present embodiment.

[0271] Also, an example of the dimensions of the components for fabricating components for the liquid crystal display device according to the eighth embodiment having the same area as those for the liquid crystal display device according to the test example 7, is shown in Fig. 32. The units of length of the parts shown in Fig. 33 are in μm, with the sub-pixel pitch at 237 × 79 (μm), and the sub-pixel area at 14784 μm^2.

[0272] The reflectivity, white display in the reflective mode, the transmittance ratio, and the white display in the transmissive mode, were each measured for the liquid crystal display device according to the test example 9 thus fabricated.

[0273] Consequently, results the same as those of the seventh embodiment shown in Table 3 were obtained.

[0274] As shown in Table 3, with the liquid crystal display device according to the test example 9, in comparison with the test example 8, the reflectivity improved, the greenness in the white display in the reflective mode and the transmissive mode was improved, drawing nearer to white.

[0275] Accordingly, it was confirmed with the liquid crystal display device according to the eighth embodiment as well, as with the liquid crystal display device according to the ninth embodiment, that a liquid crystal display device having display with excellent color reproduction in both the reflective mode and transmissive mode can be obtained, and regardless of the shape of the transmissive area and pigment layer non-formation area (pigment layer formation area), adjusting the area of the transmissive area and pigment layer non-formation area (pigment layer formation area) for each color enables a liquid crystal display device capable of display with excellent color reproduction in both the reflective mode and transmissive mode to be obtained.

[Advantages]

[0276] As described above, according to the present invention, the percentage of transmissive area in the sub-pixels is a percentage according to the spectral properties of the illumination light, so even in the event that the spectral properties of the illumination light used for transmissive display is not uniform, deterioration in color reproduction due to this can be suppressed.

[0277] Also, with the liquid crystal display device according to the present invention, the pigment layers are formed on the entirety of the area overlapping the transmissive area in a planar manner, and an area excluding a part of an area overlapping the reflective area in a planar manner, with a pigment layer formation area where the pigment layers are formed, and a pigment layer non-formation area at a part of an area overlapping the reflective area in a planar manner, so the light obtained by passing trough the color filter twice when in the reflective mode is the sum of the uncolored light which has passed through the pigment layer non-formation area and the colored light which has passed through the pigment layer formation area.

[0278] On the other hand, light obtained by passing through the color filter once when in the transmissive mode is all colored. Accordingly, the difference in concentration between the light obtained by passing through the color filter twice when in the reflective mode and the light obtained by passing through the color filter once when in the transmissive mode can be reduced.

[0279] Consequently, a color transflective liquid crystal display device capable of display with similarly good colorization and high visual recognition for both the reflective mode and transmissive mode, can be realized.

[0280] Moreover, with the liquid crystal display device according to the present invention, the area of the pigment layer formation area differs between at least one color pigment layer of the pigment layers and another color pigment layer, so the color properties of the color filter can be adjusted by changing the area of the pigment layer formation area, thereby improving color reproduction, and realizing a liquid crystal display device having excellent display quality.

[0281] Also, with the liquid crystal display device according to the present invention, a transparent film for smoothen the steps between the pigment layer formation area and a the areas where the pigment layers have not been provided is provided, so adverse effects due to the steps between the pigment layer formation area and the areas where the pigment layers have not been provided can be done away with, thereby improving the reliability of the liquid crystal display device.

Claims

1. A liquid crystal display device, comprising: a liquid crystal display panel formed of liquid crystal sandwiched between a pair of mutually facing substrates, having pixels comprising multiple sub-pixels each corresponding to different colors; and an illumination device provided to the opposite side of said liquid crystal display panel as to the observation side, for illuminating said liquid crystal display panel with illumination light;

    having a transflective layer disposed on the opposite side of said liquid crystal as to the observation side with a transmissive portion for transmitting said illumination light formed thereto, wherein the area of a transmissive area corresponding to said transmissive portion at at least one sub-pixel out of multiple sub pixels, and the area of a transmissive area corresponding to said transmissive portion at another sub-pixel, differ;

    and a color filter provided corresponding to each of said sub-pixels, for transmitting light of a wavelength corresponding to the color of each sub-pixel.

2. A liquid crystal display device according to Claim 1, wherein the area of the transmissive area at each sub-pixel is an area according to the spectral properties of said illumination light.

3. A liquid crystal display device according to Claim 2, wherein the area of the transmissive area at each sub-pixel is an area according to the luminance of the wavelength of said illumination light corresponding to the color of said sub-pixel.

4. A liquid crystal display device according to Claim 3, wherein the area of said transmissive area at a sub-pixel of a color corresponding to a wavelength of said illumination light with great luminance is smaller than the area of said transmissive area at a sub-pixel of a color corresponding to a wavelength of said illumination light with small luminance.

5. A liquid crystal display device according to any one of Claim 1 through Claim 4, wherein the area of the transmissive area at each of said sub-pixels differs for each sub-pixel corresponding to a different color.

6. A liquid crystal display device according to any one of Claim 1 through Claim 4, wherein the area of the transmissive area at each of said sub-pixels differs according to the position of said sub-pixel within the substrate face of said liquid crystal display panel.

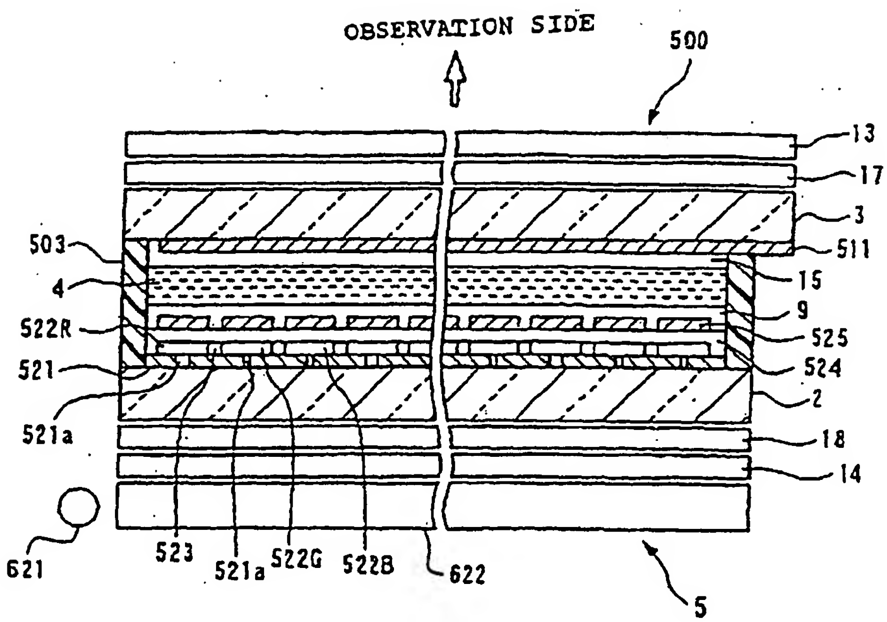
7. A liquid crystal display device according to any one of Claim 1 through Claim 6, wherein said transmissive portion is an opening portion formed in said transflective layer corresponding to each of said sub-pixels.

8. A liquid crystal display device according to Claim 7, wherein said opening portion comprises opening parts of generally the same area formed mutually separated, the number thereof according to the area of the transmissive area at said sub-pixels.

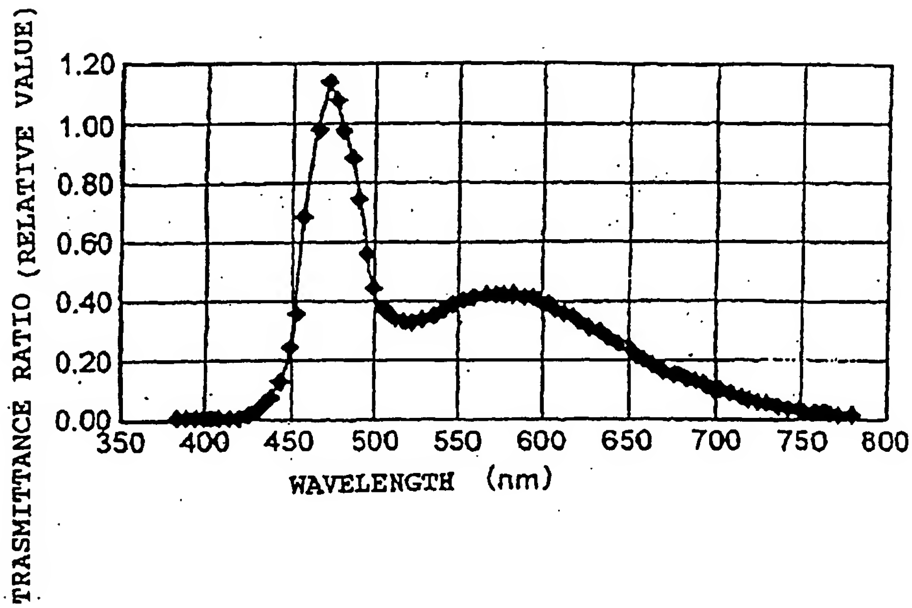
9. A liquid crystal display device according to any one of Claim 1 through Claim 6, wherein said transflective layer has said transmissive portion formed such that an area following at least one side of a plurality of sides defining each sub pixel serves as said transmissive area.

10. Electronic equipment, comprising the liquid crystal display device according to any one of Claim 1 through Claim 9.

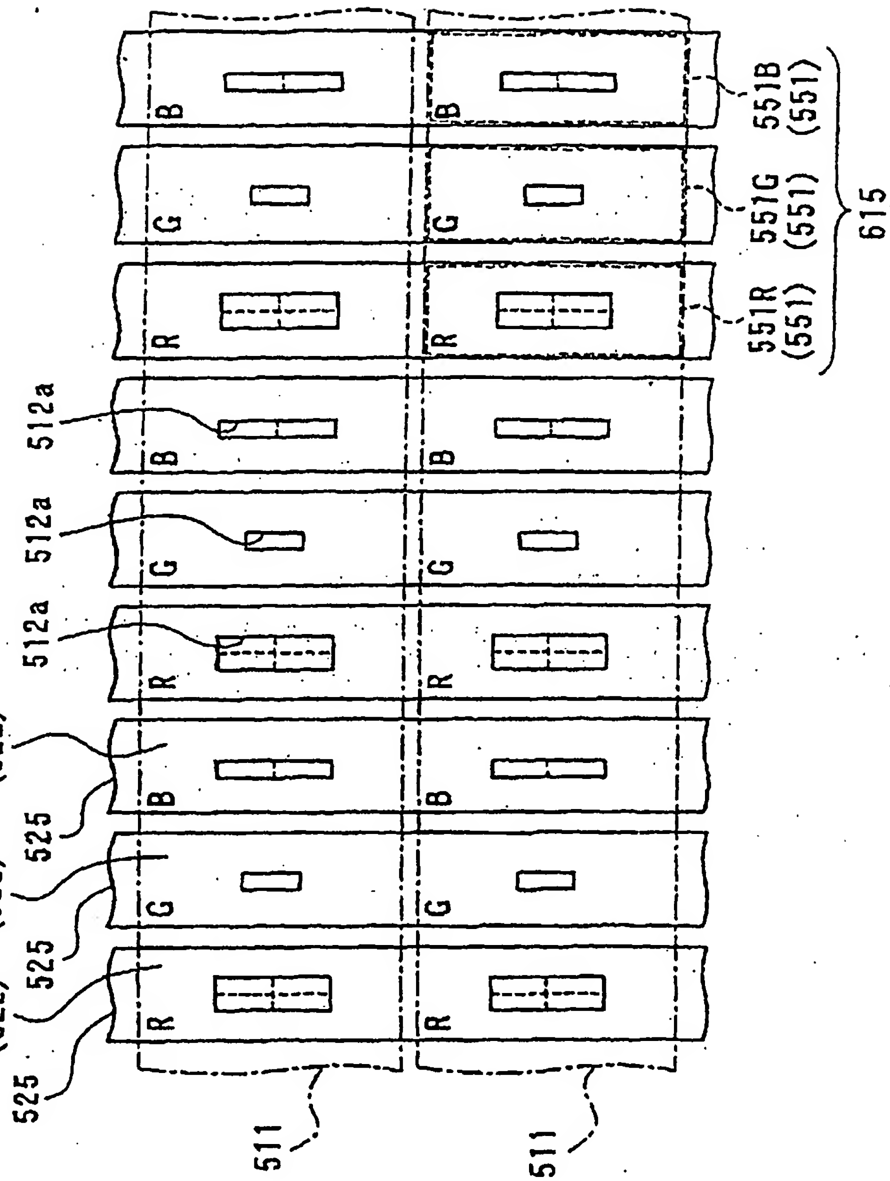
(FIG. 1)


OBSERVATION SIDE
500
13
17
3
511
15
9
525
524
2
18
14
5
503
4
522R
521
521a
621
523
521a
522G
522B
622

〔F I G. 2〕

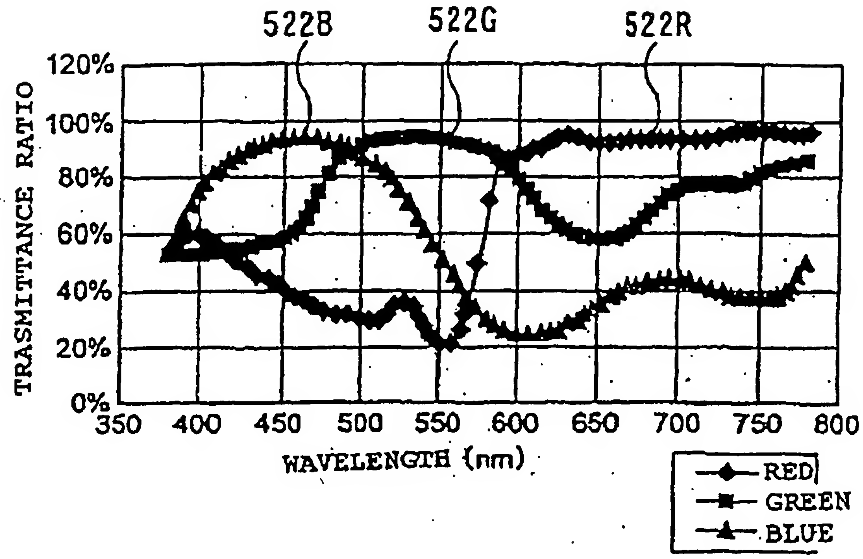

TRASMITTANCE RATIO (RELATIVE VALUE)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
350 400 450 500 550 600 650 700 750 800
WAVELENGTH (nm)

(FIG. 3)

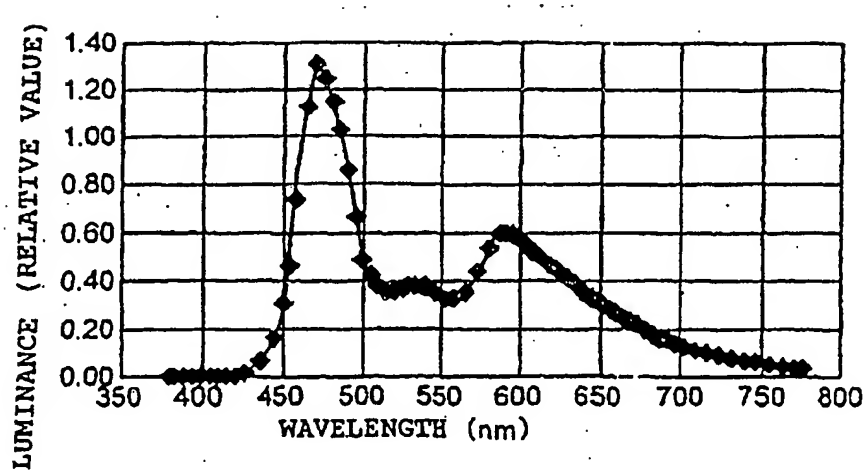


551B
(551)
551G
(551)
551R
(551)
615
512a
512a
512a
522B
(522)
525
522G
(522)
525
522R
(522)
525
511
511
R
G
B

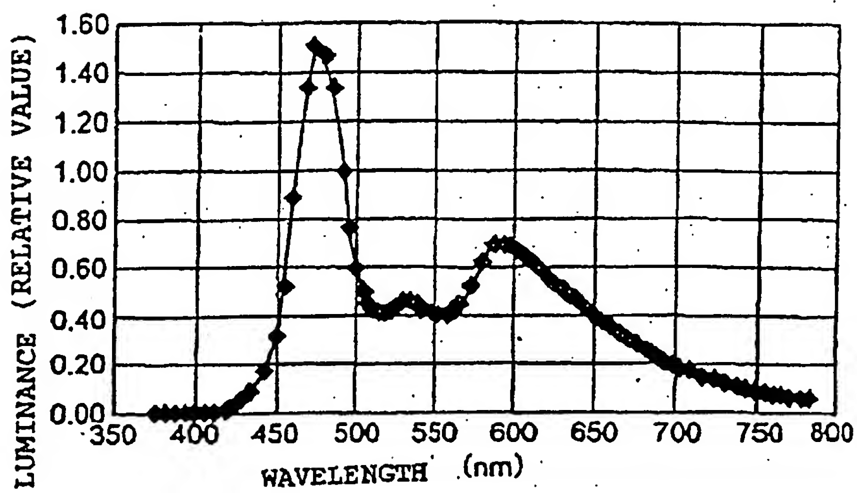
[F I G. 4]


522B
522G
522R
120%
100%
80%
60%
40%
20%
0%
TRASMITTANCE RATIO
350
400
450
500
550
600
650
700
750
800
WAVELENGTH (nm)
RED
GREEN
BLUE

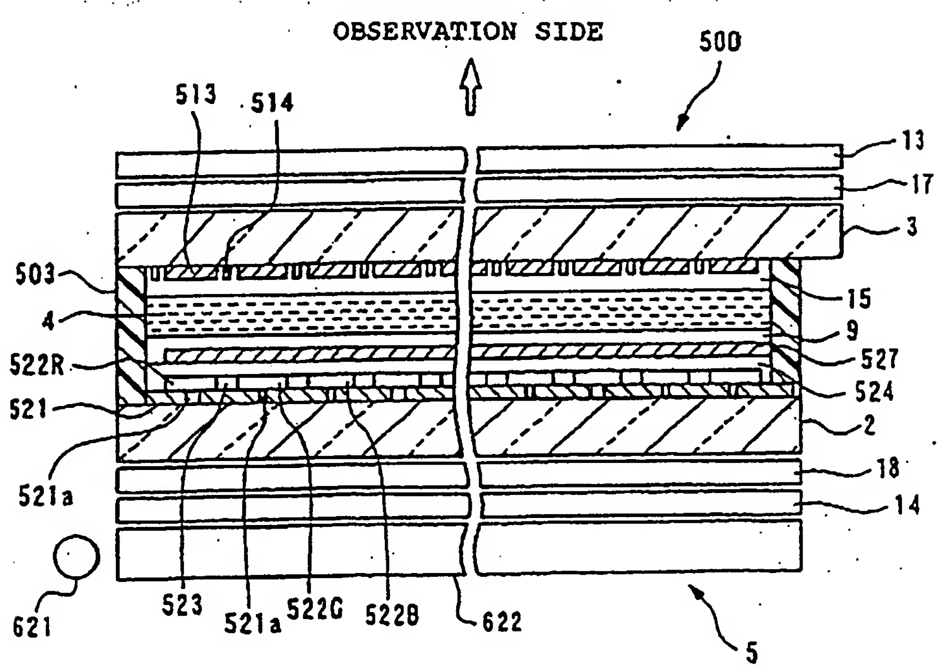
[F I G. 5]


1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
LUMINANCE (RELATIVE VALUE)
350
400
450
500
550
600
650
700
750
800
WAVELENGTH (nm)

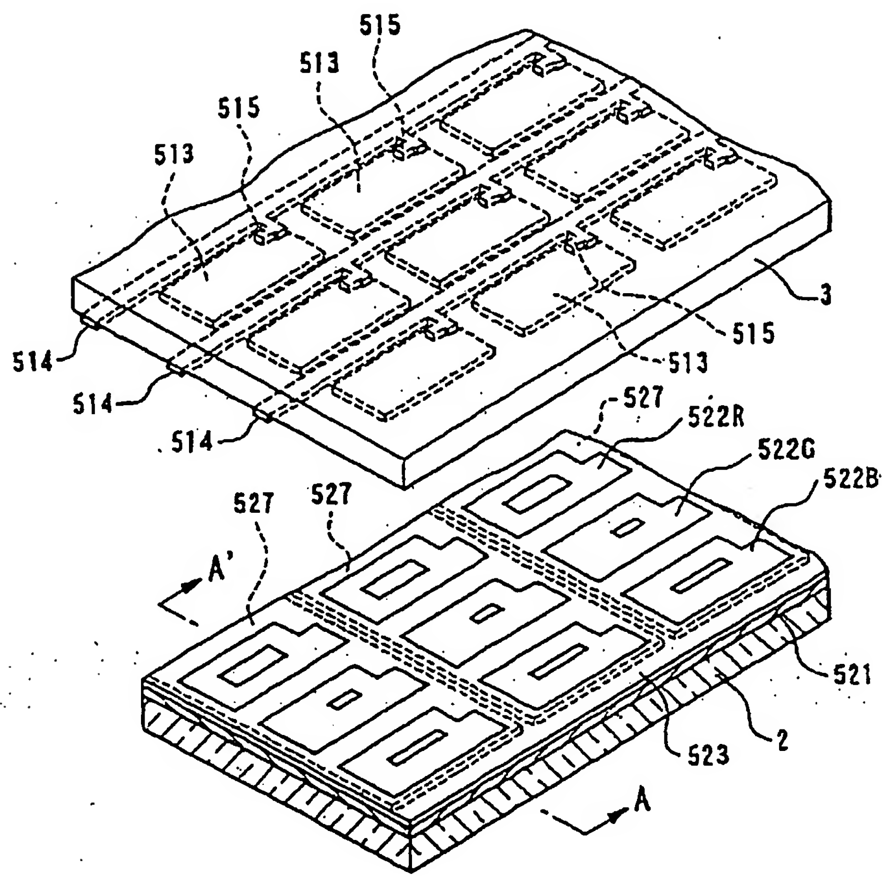
[FIG. 6]


LUMINANCE (RELATIVE VALUE)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
350 400 450 500 550 600 650 700 750 800
WAVELENGTH (nm)

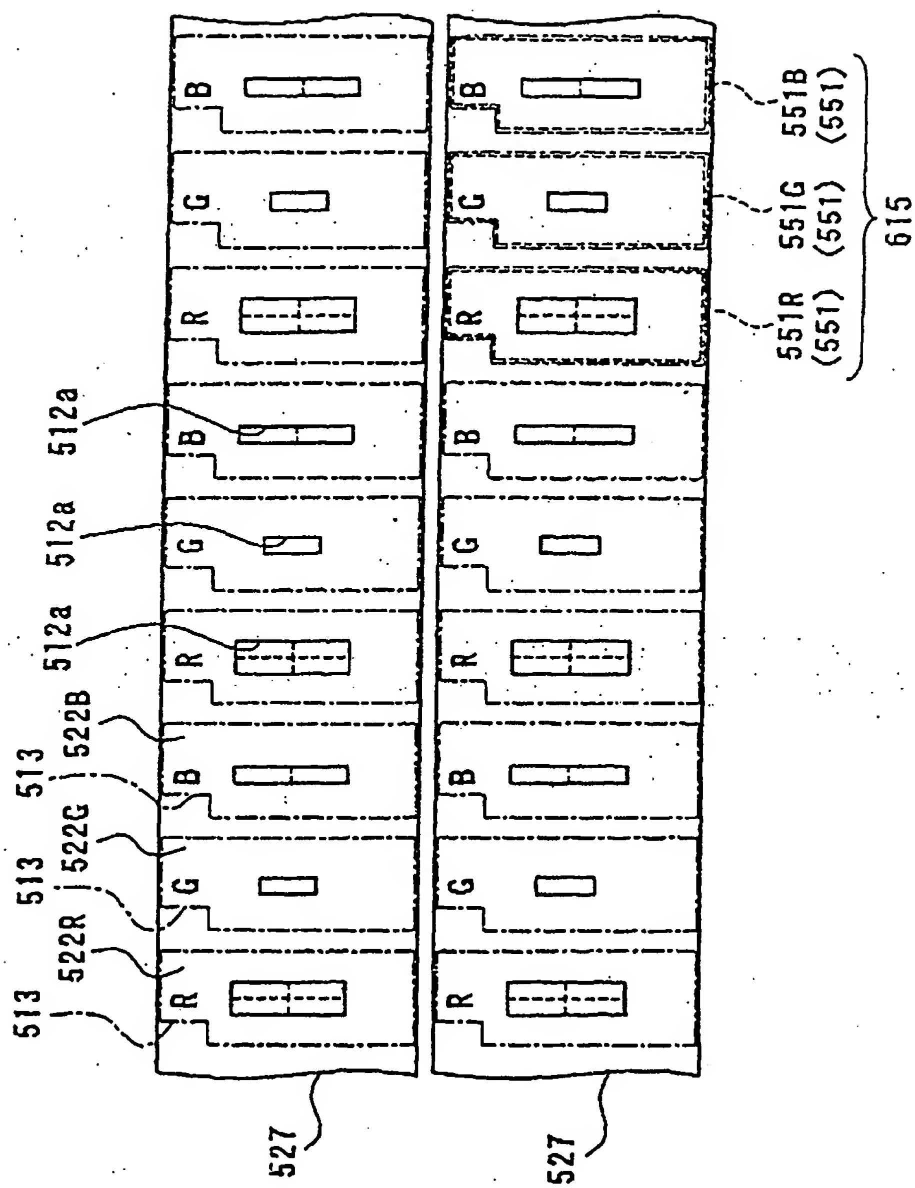
[FIG. 7]


OBSERVATION SIDE
500
513
514
13
17
3
503
4
522R
521
521a
15
9
527
524
2
18
14
621
523
521a
522G
522B
622
5

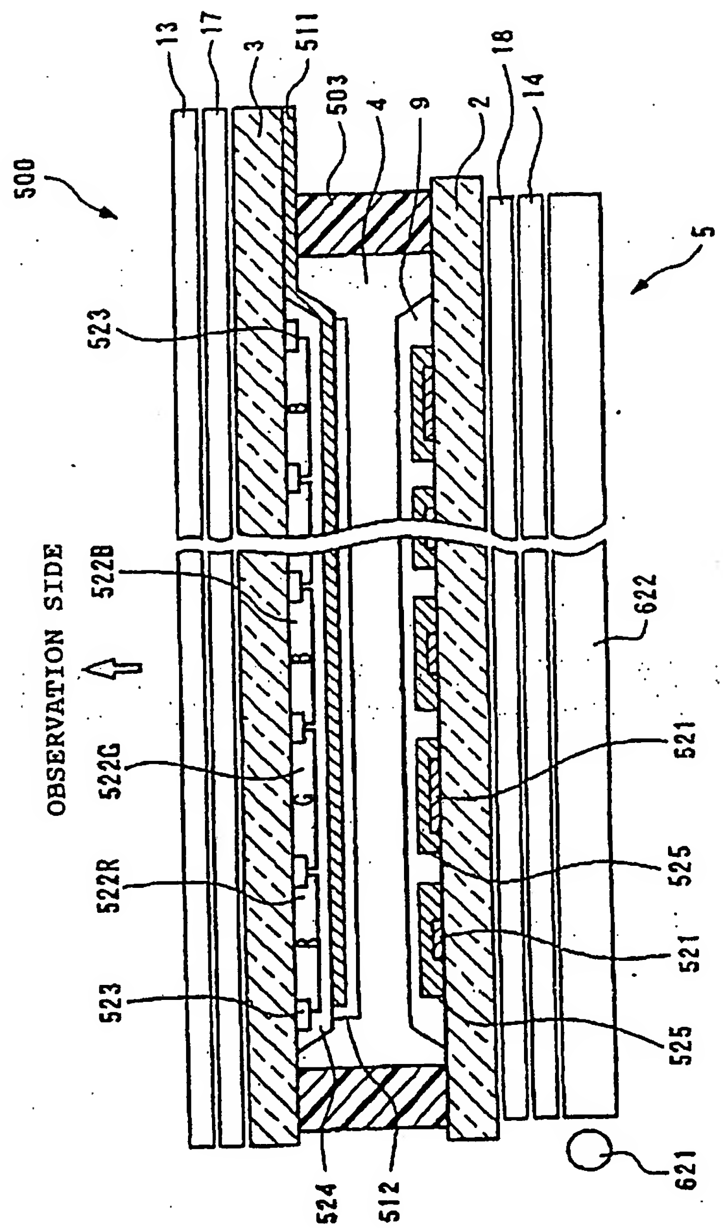
〔F I G. 8〕


515
513
515
513
3
515
513
514
514
514
527
522R
522G
522B
527
527
A'
521
2
523
A

[FIG. 9]

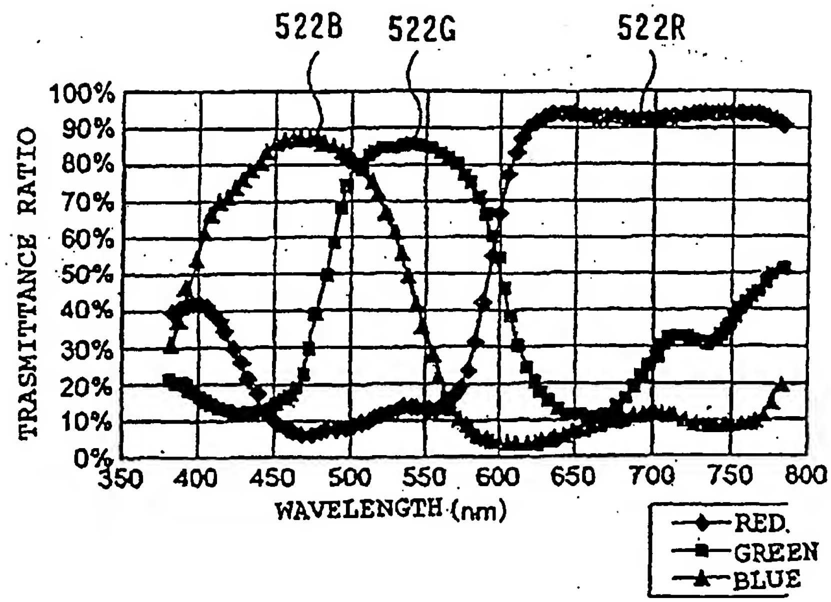

551B (551)
551G (551)
551R (551)
615
512a
512a
512a
522B
513
522G
513
522R
513
527
527
B
G
R
B
G
R
B
G
R
B
G
R
B
G
R
B
G
R

〔FIG. 10〕

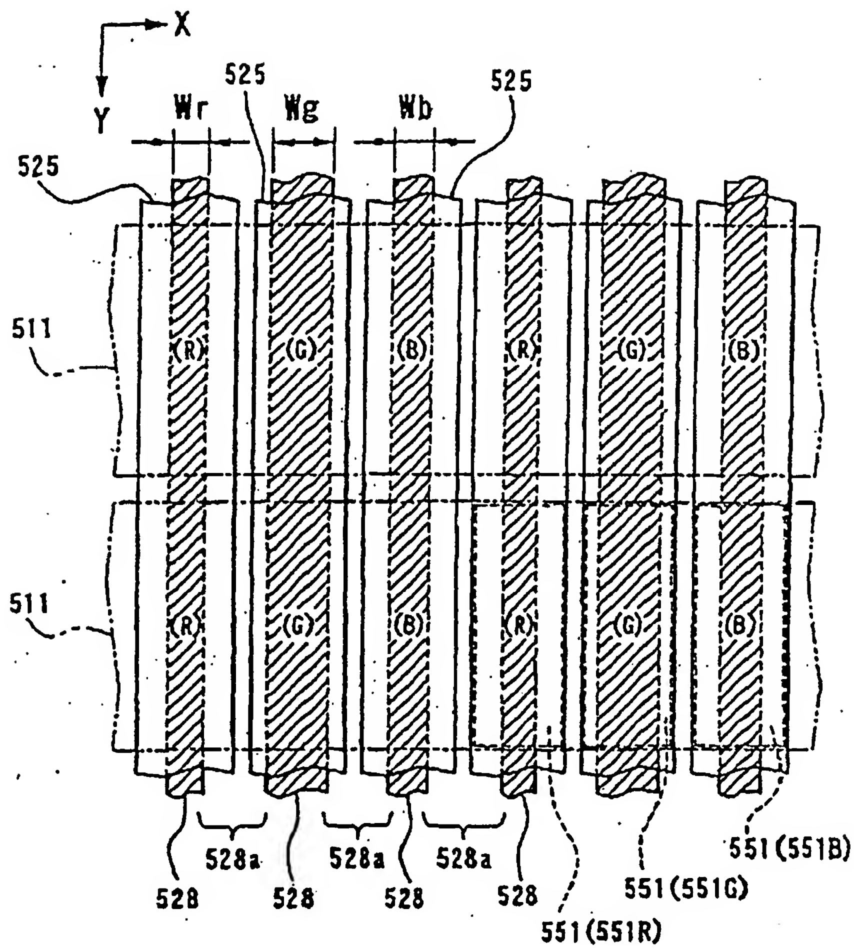


500
13
17
3
511
503
4
9
2
18
14
5
523
522B
OBSERVATION SIDE
522G
522R
523
622
521
525
521
525
524
512
621

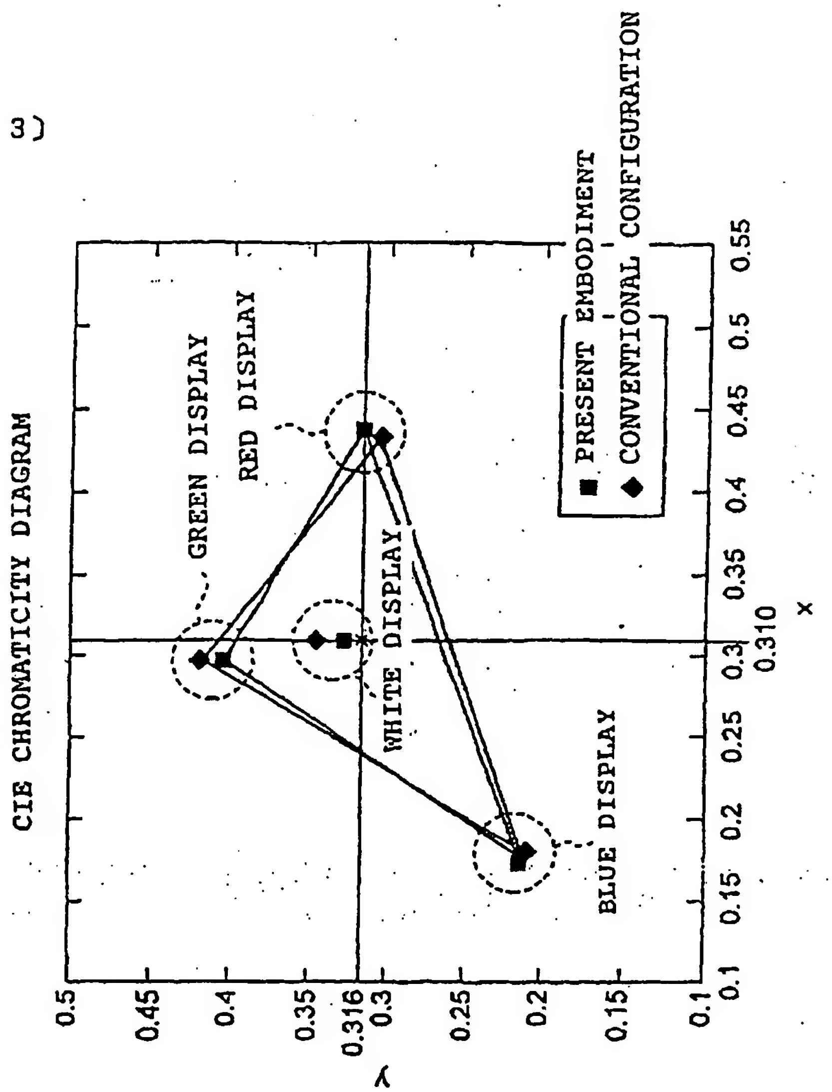
〔FIG. 11〕


522B
522G
522R
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
TRASMITTANCE RATIO
350
400
450
500
550
600
650
700
750
800
WAVELENGTH (nm)
RED.
GREEN
BLUE

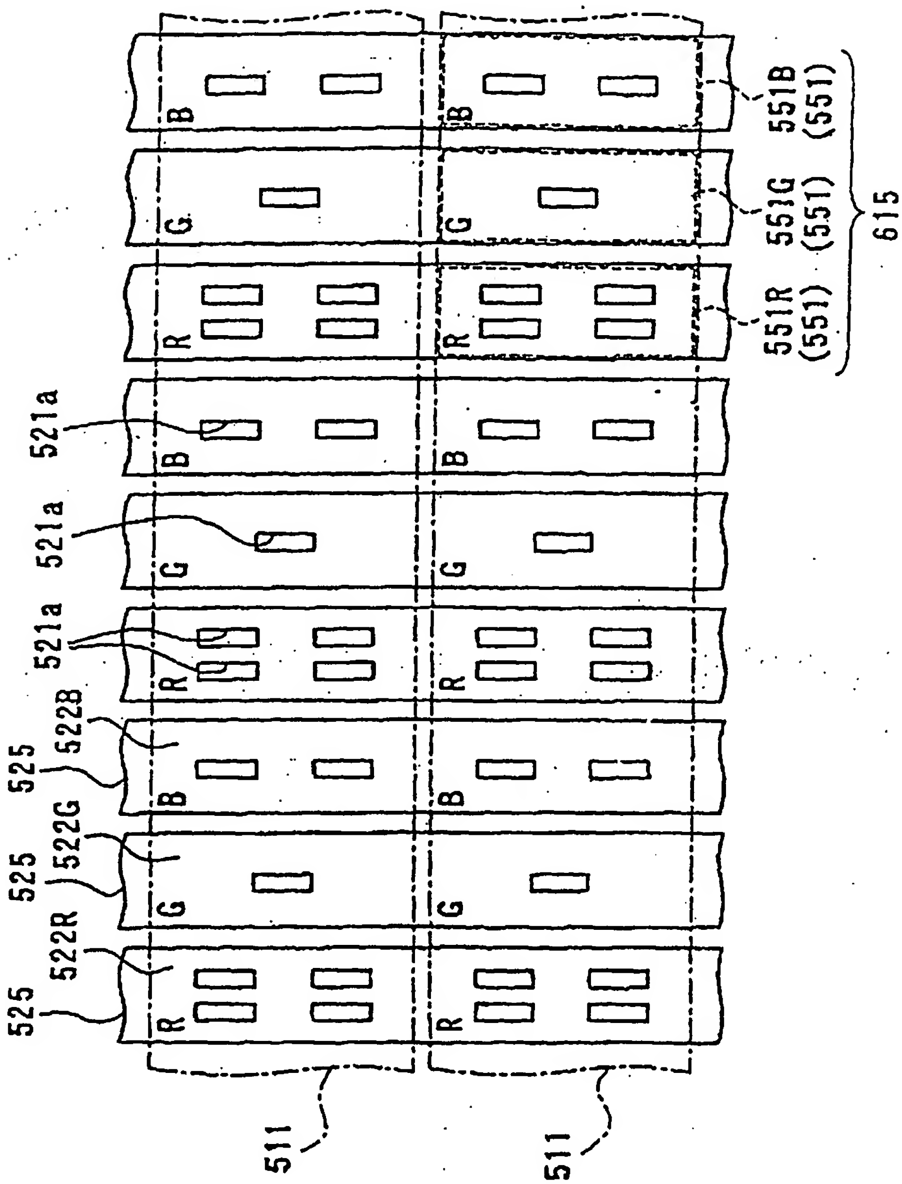
〔FIG. 12〕


X
Y
525
525
525
Wr
Wg
Wb
511
511
(R)
(G)
(B)
(R)
(G)
(B)
(R)
(G)
(B)
(R)
(G)
(B)
528
528
528
528
528a
528a
528a
551(551R)
551(551G)
551(551B)

[FIG. 13]

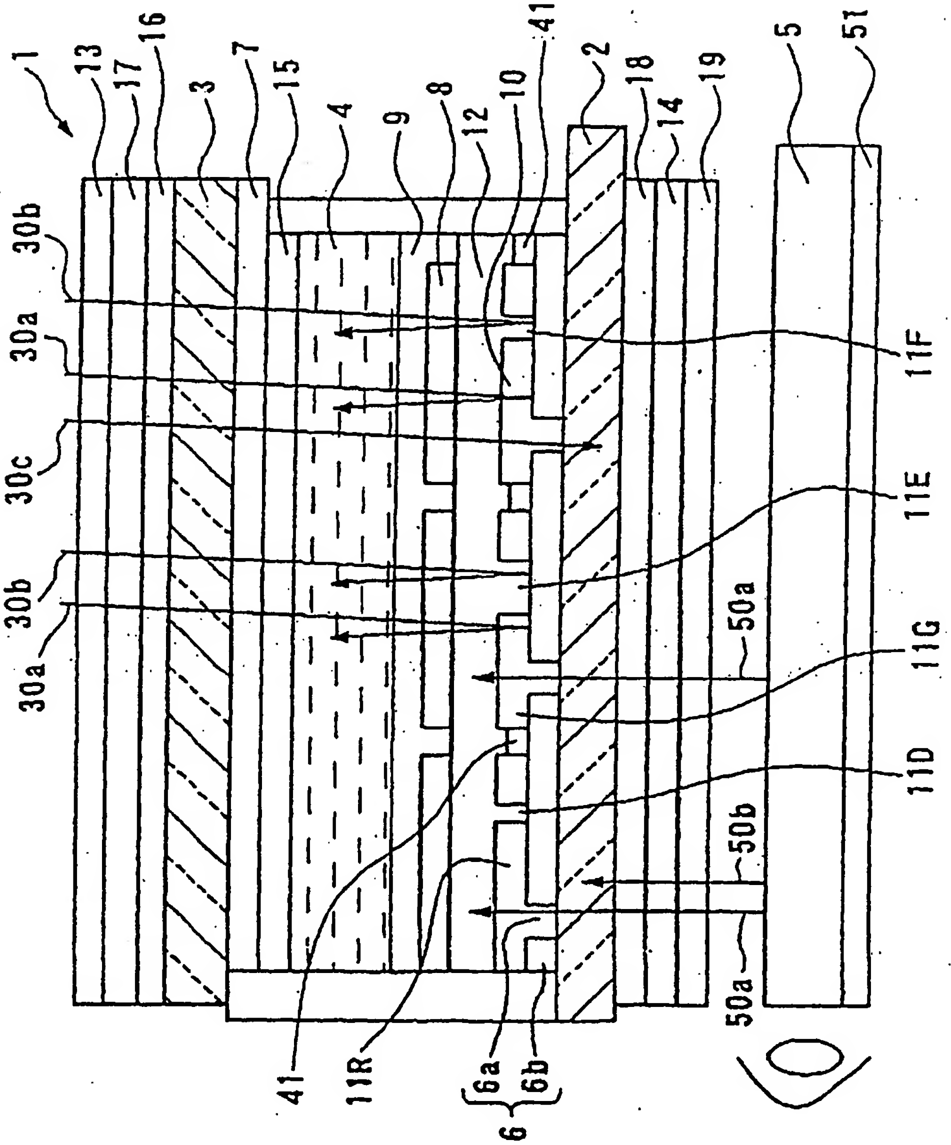

CIE CHROMATICITY DIAGRAM
GREEN DISPLAY
RED DISPLAY
WHITE DISPLAY
BLUE DISPLAY
PRESENT EMBODIMENT
CONVENTIONAL CONFIGURATION
x
y

〔FIG. 14〕

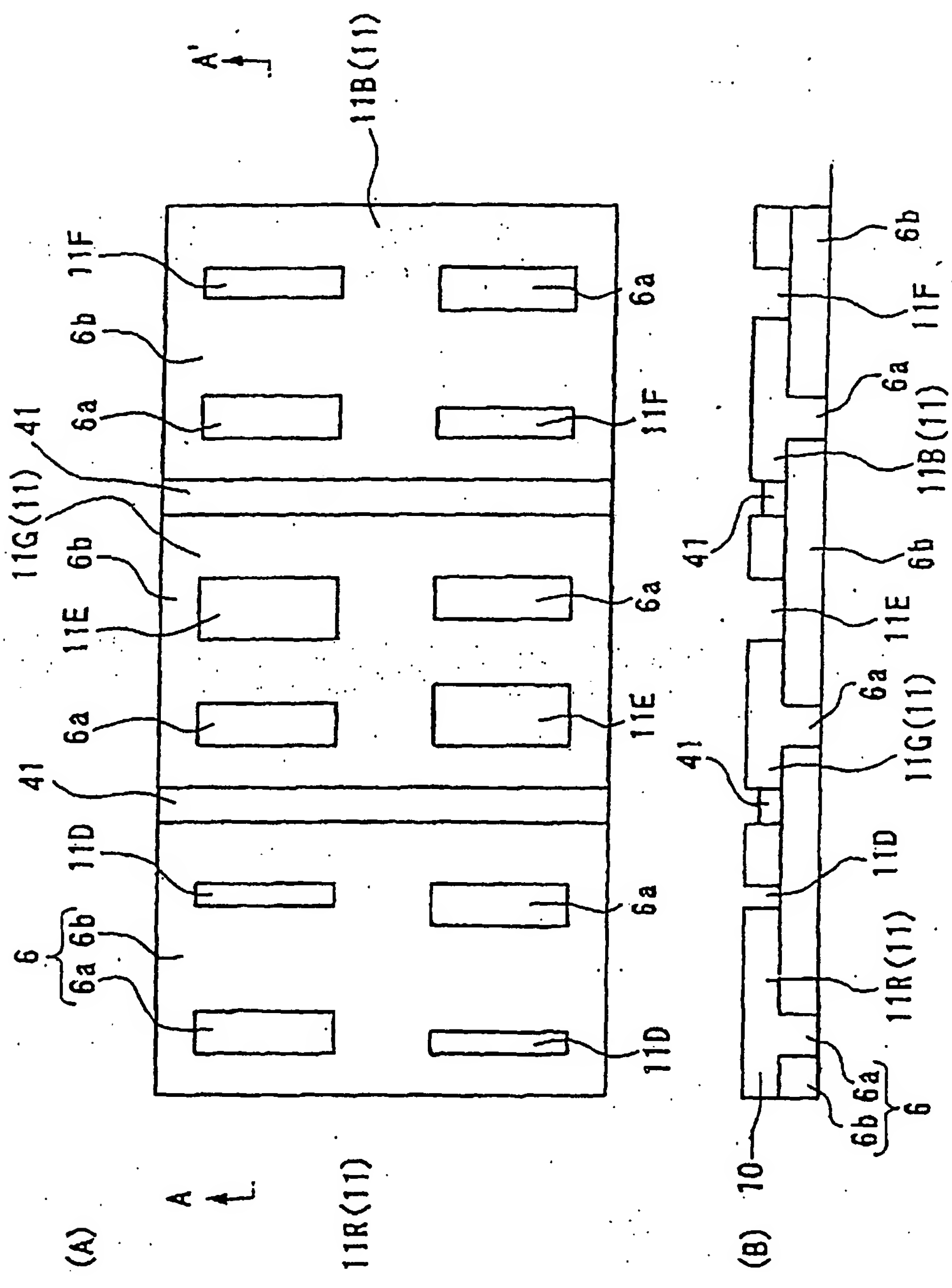


521a
521a
521a
525
522B
525
522G
525
522R
R
G
B
551B
(551)
551G
(551)
551R
(551)
615
511
511

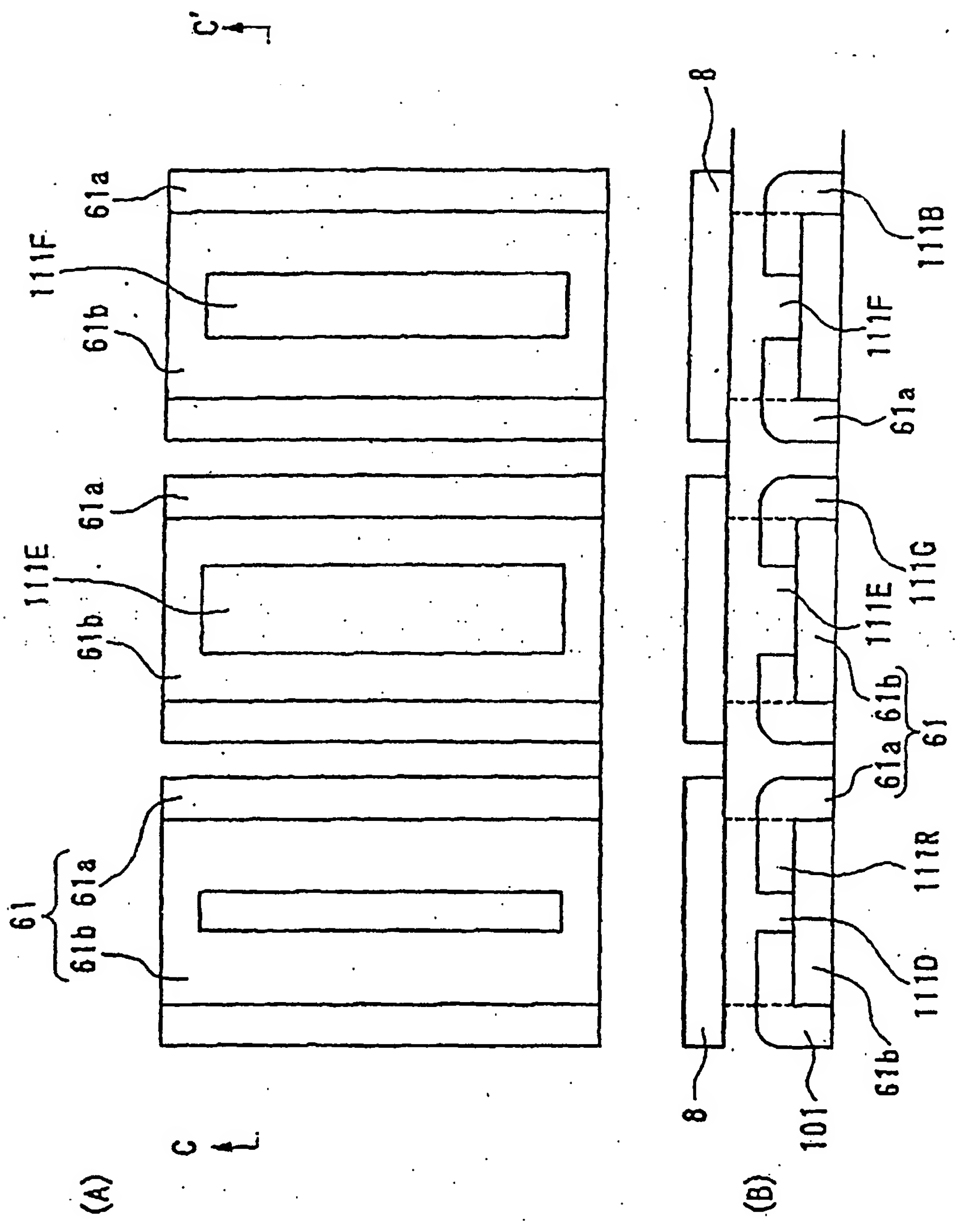
〔FIG. 15〕


1
13
17
16
3
7
15
4
9
8
12
10
41
2
18
14
19
5
51
30b
30a
30c
30b
30a
11F
11E
11G
11D
50a
50b
50a
41
11R
6a
6b
6

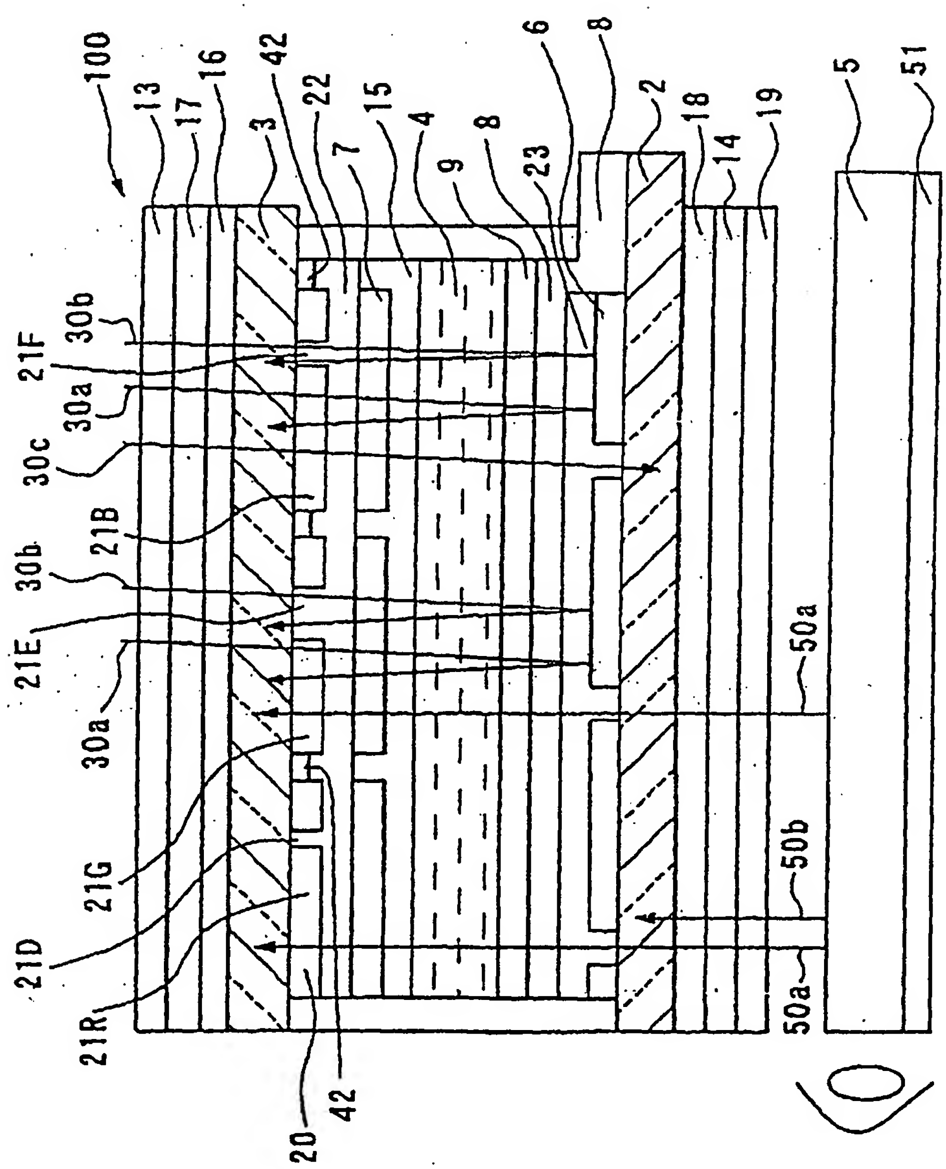
〔FIG. 16〕



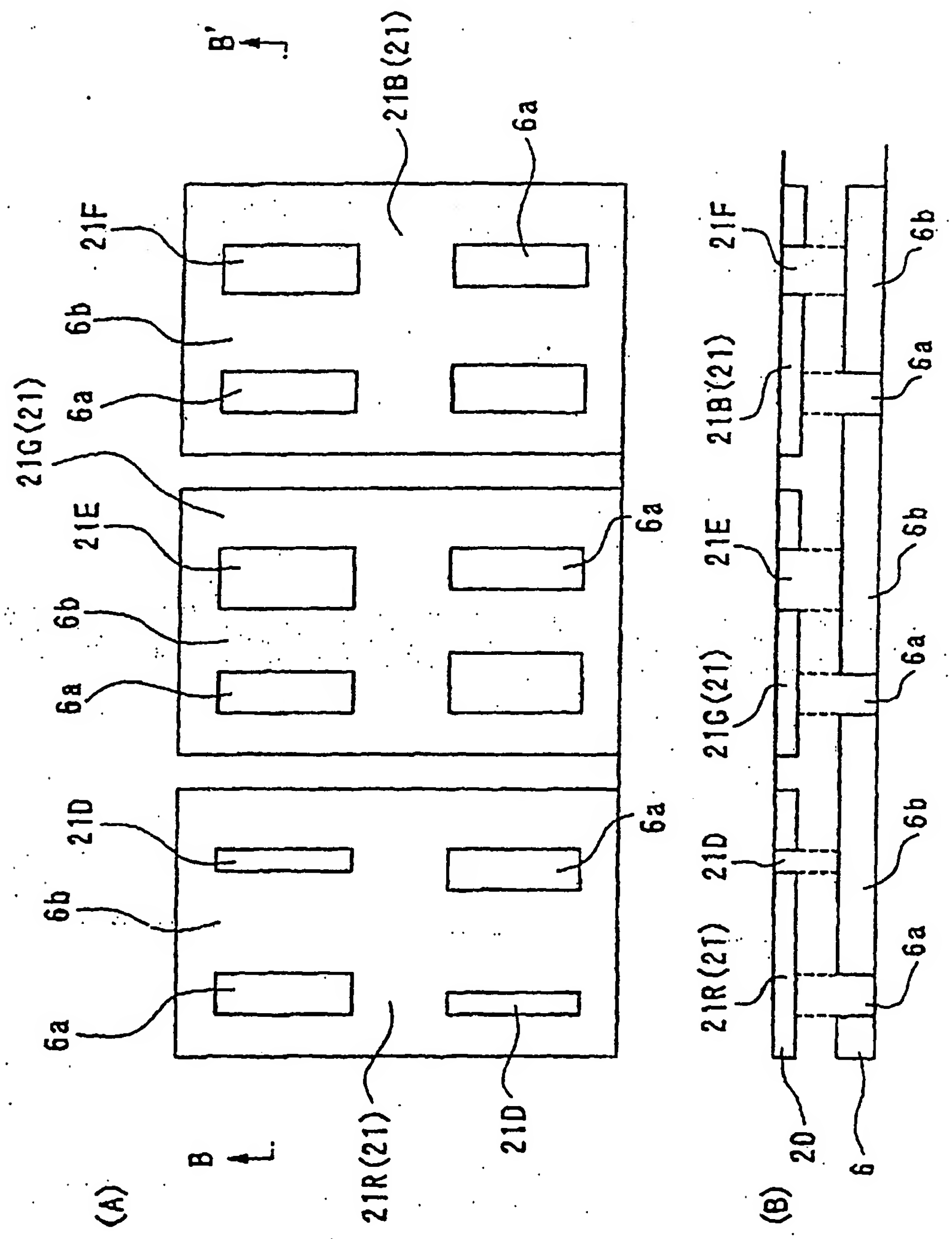
〔FIG. 17〕



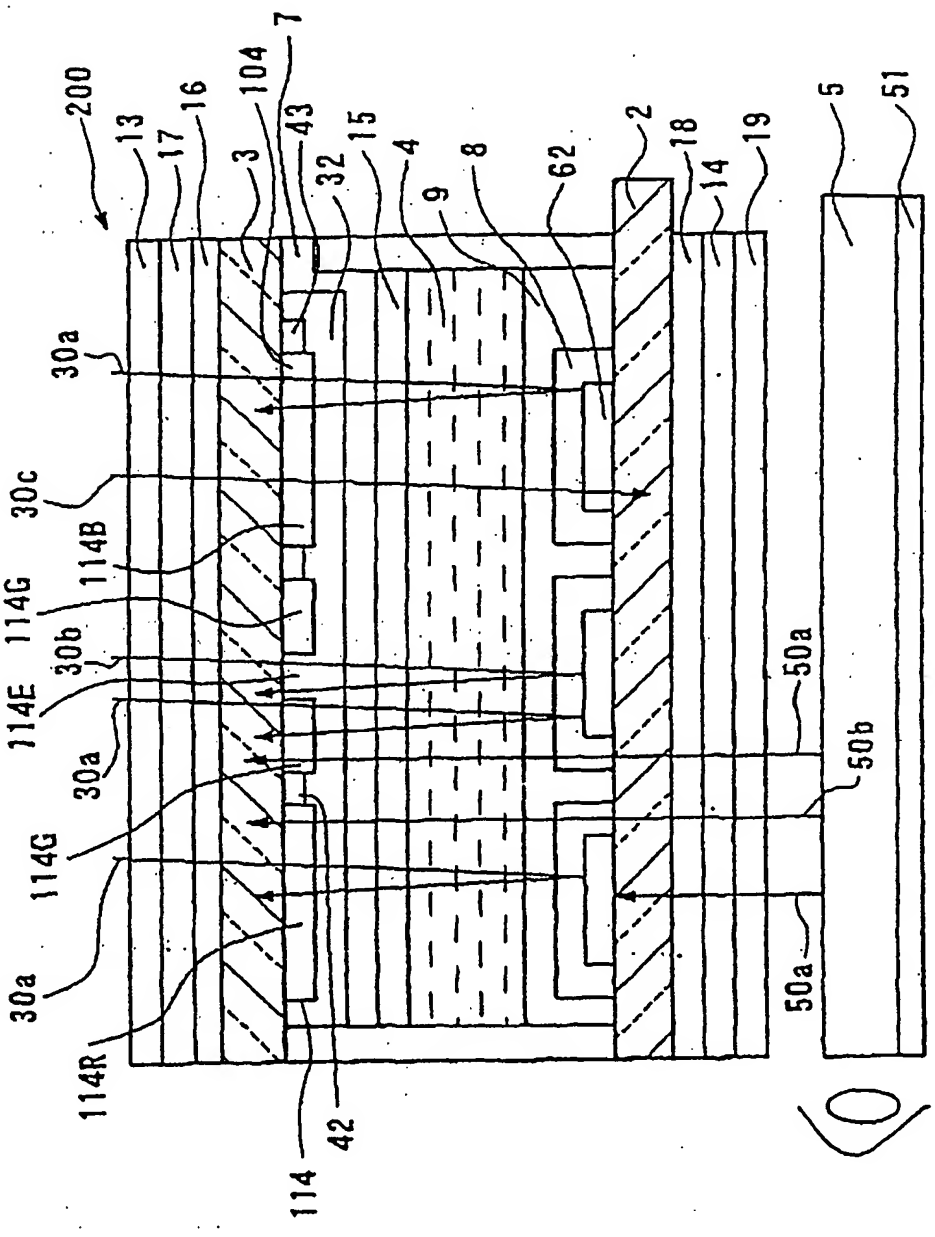
[FIG. 18]


100
13
17
16
3
42
22
7
15
4
9
8
23
6
8
2
18
14
19
5
51
30b
21F
30a
30c
21B
30b
21E
30a
21G
21D
21R
20
42
50a
50b
50a

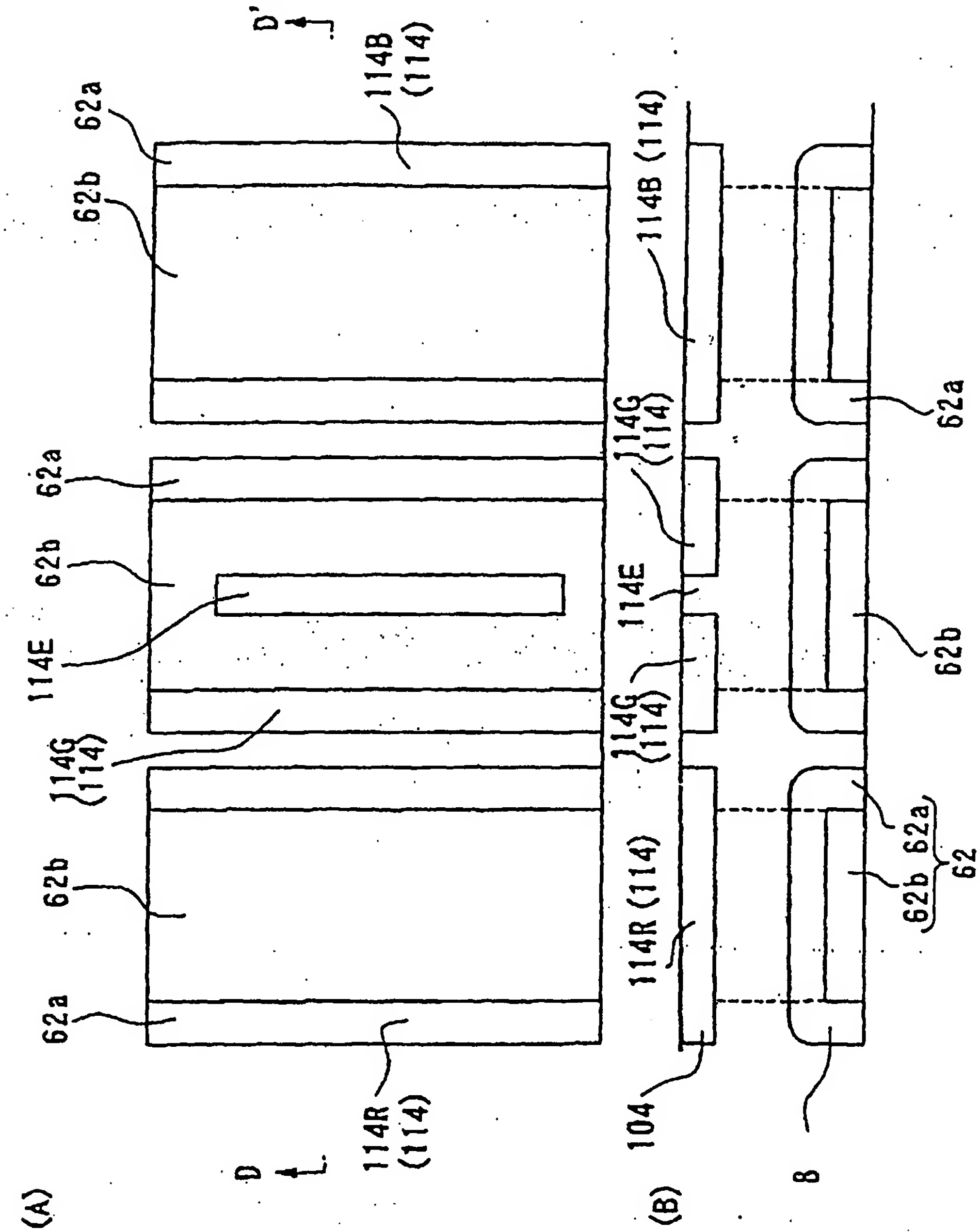
〔FIG. 19〕



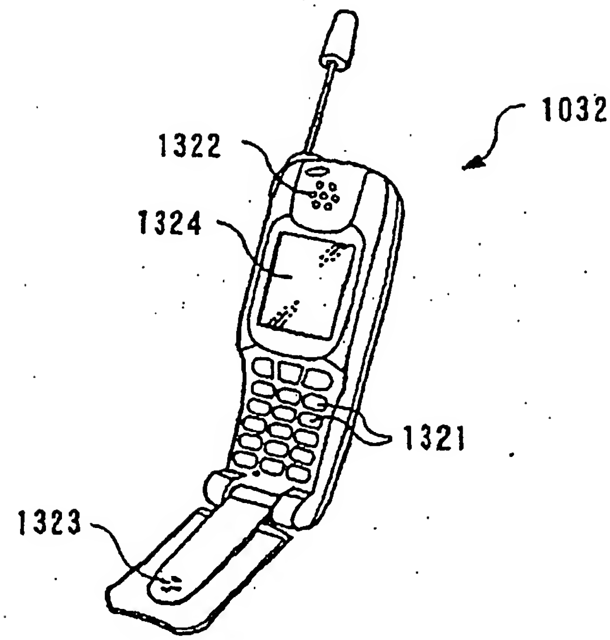
[FIG. 20]


200
13
17
16
3
104
7
43
32
15
4
9
8
62
2
18
14
19
5
51
30a
30c
114B
114G
30b
114E
30a
114G
30a
114R
114
42
50a
50b
50a

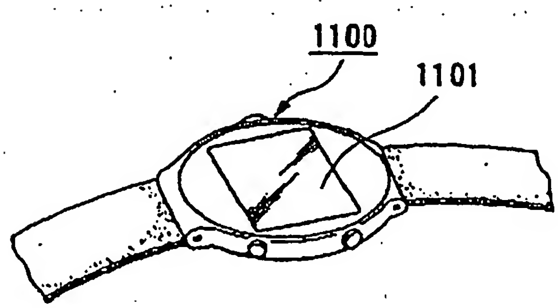
〔FIG. 21〕


(A)
D
D'
114R
(114)
62a
62b
114G
(114)
114E
62b
62a
62b
62a
114B
(114)
(B)
104
B
114R (114)
114G
(114)
114E
114G
(114)
114B (114)
62b
62a
62
62b
62a

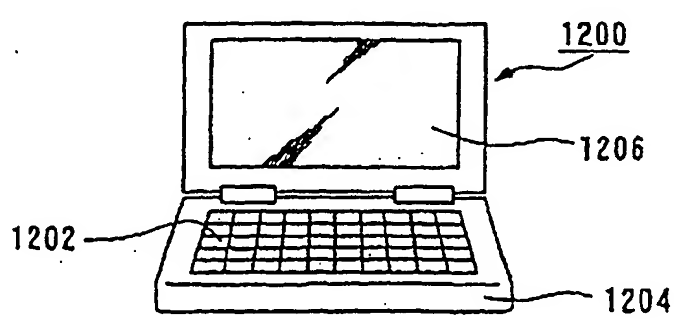
〔FIG. 22〕



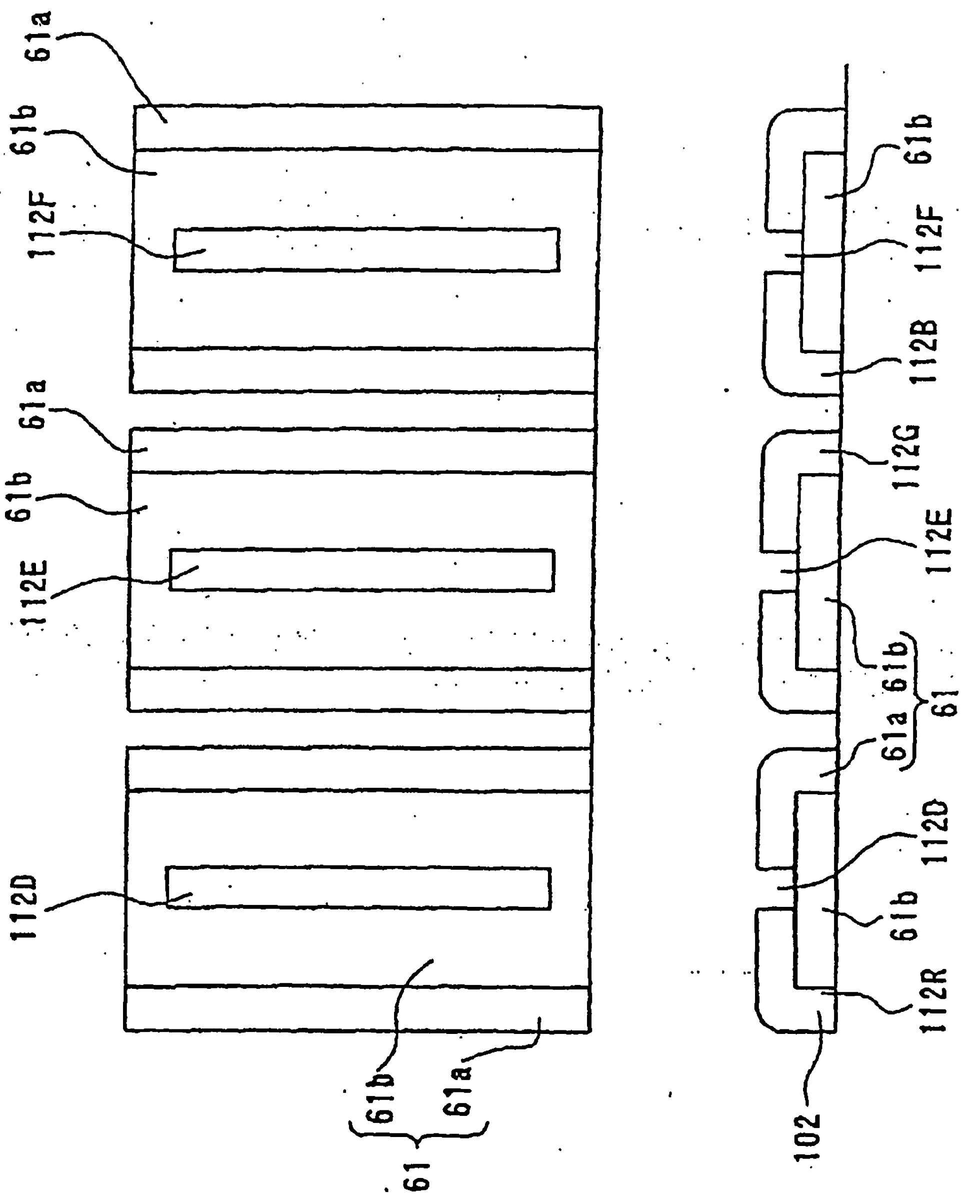
〔FIG. 23〕



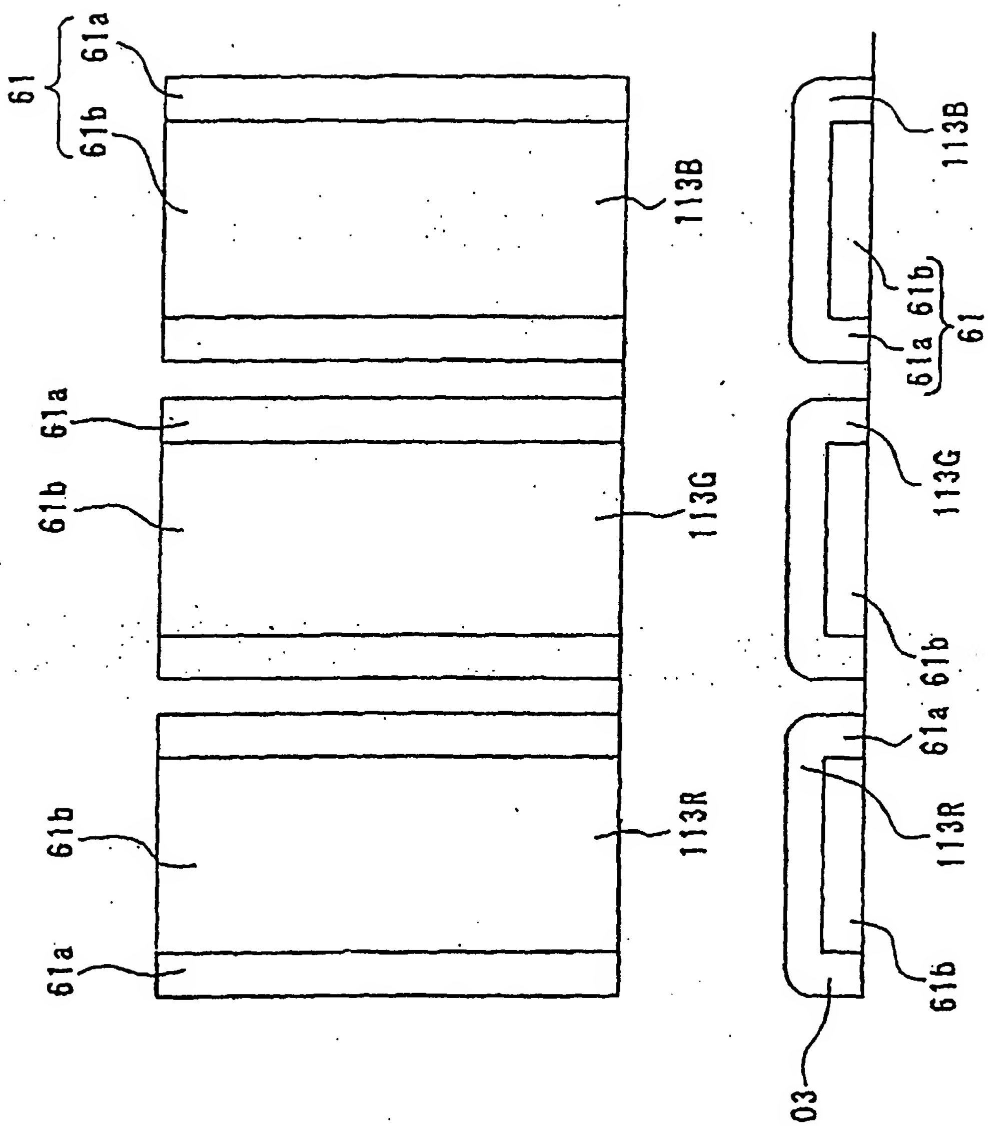
〔FIG. 24〕



(FIG. 25)

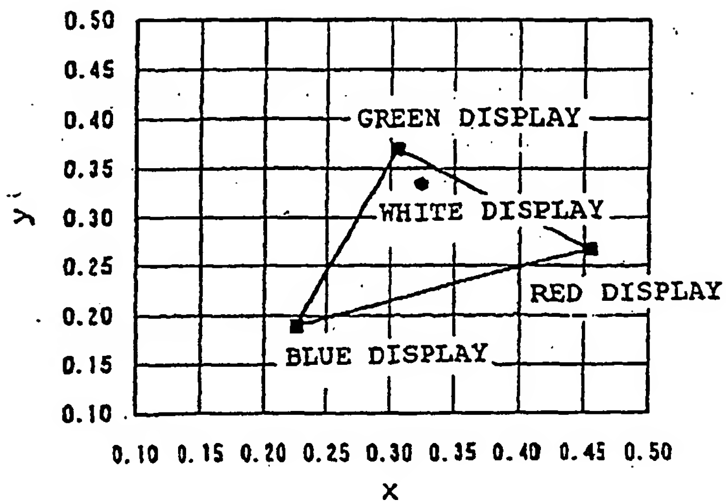

61a
61b
112F
61a
61b
112E
112D
61b
61a
61
61b
112F
112B
112G
112E
61b
61a
61
112D
61b
112R
102

〔FIG. 26〕

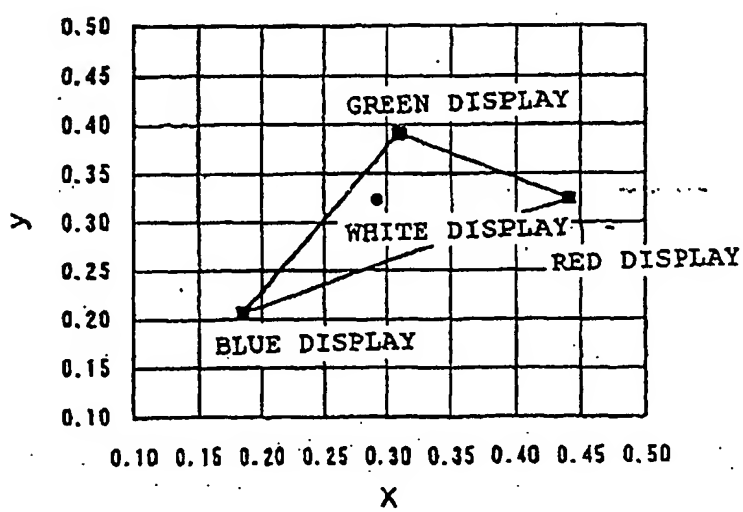

61
61a
61b
113B
61a
61b
113G
61b
61a
113R
113B
61b
61a
61
113G
61b
61a
113R
61b
103

〔FIG. 27〕

(A)

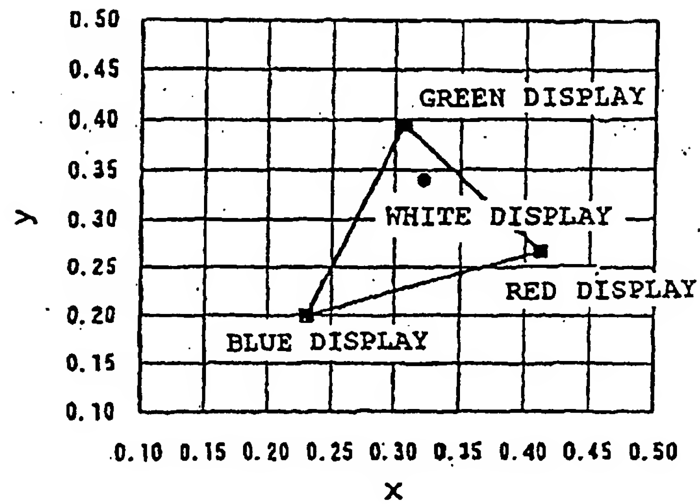

0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
y
GREEN DISPLAY
WHITE DISPLAY
RED DISPLAY
BLUE DISPLAY
0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
x

(B)

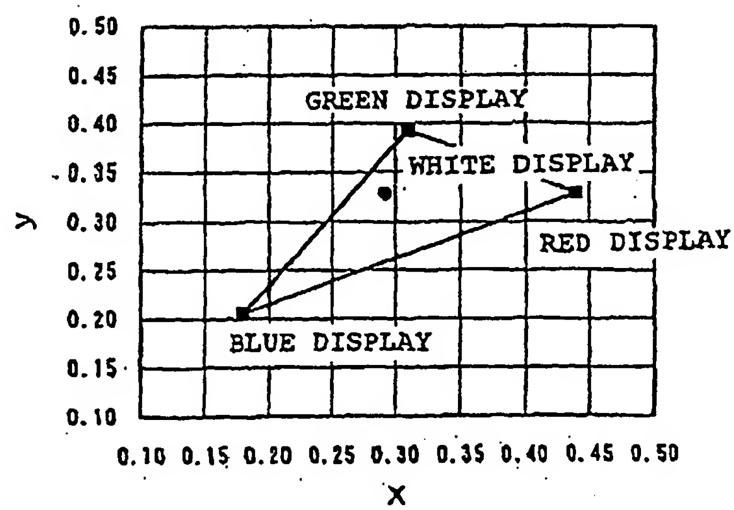

0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
y
GREEN DISPLAY
WHITE DISPLAY
RED DISPLAY
BLUE DISPLAY
0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
x

〔FIG. 28〕

(A)

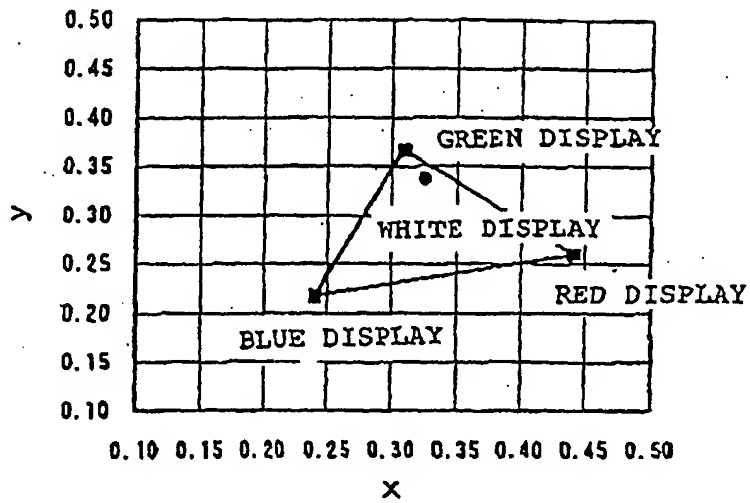

0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
y
GREEN DISPLAY
WHITE DISPLAY
RED DISPLAY
BLUE DISPLAY
0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
x

(B)

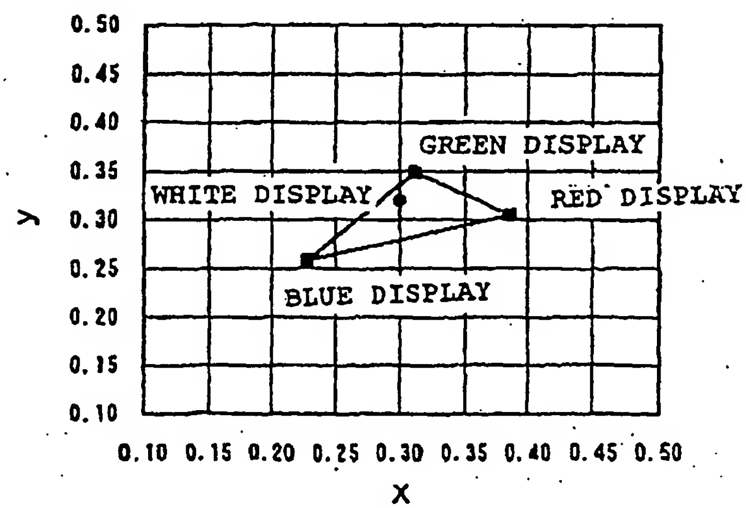

0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
y
GREEN DISPLAY
WHITE DISPLAY
RED DISPLAY
BLUE DISPLAY
0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
x

〔FIG. 29〕

(A)

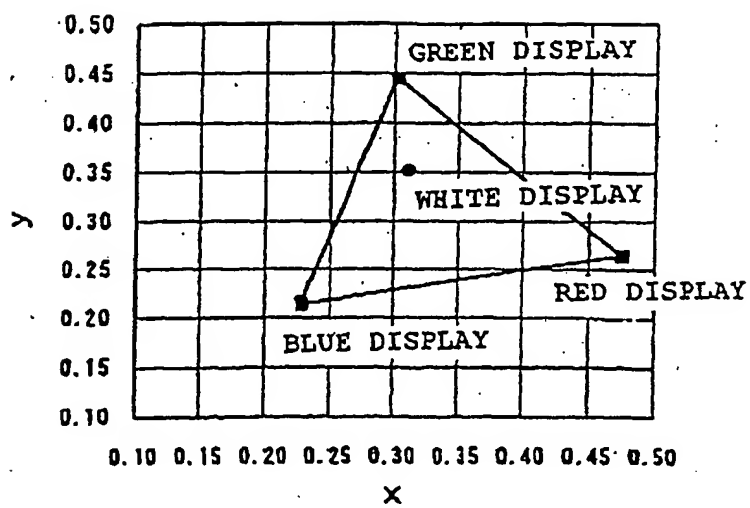

0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
y
GREEN DISPLAY
WHITE DISPLAY
RED DISPLAY
BLUE DISPLAY
0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
x

(B)


0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
y
GREEN DISPLAY
WHITE DISPLAY
RED DISPLAY
BLUE DISPLAY
0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
x

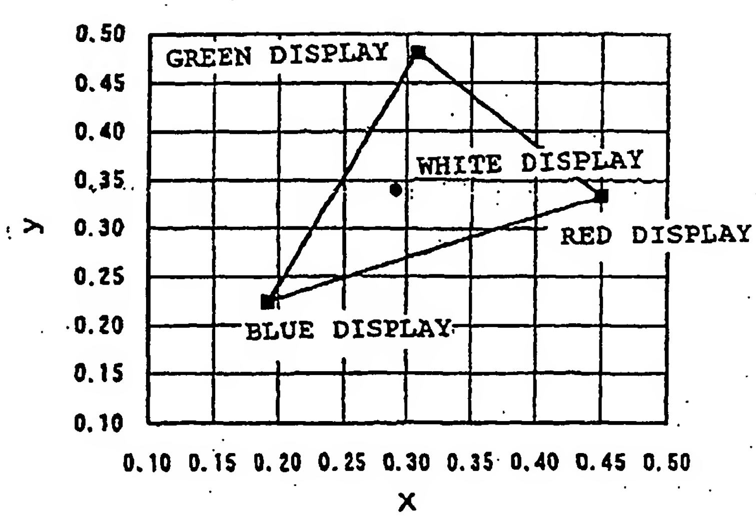
[FIG. 30]

(A)



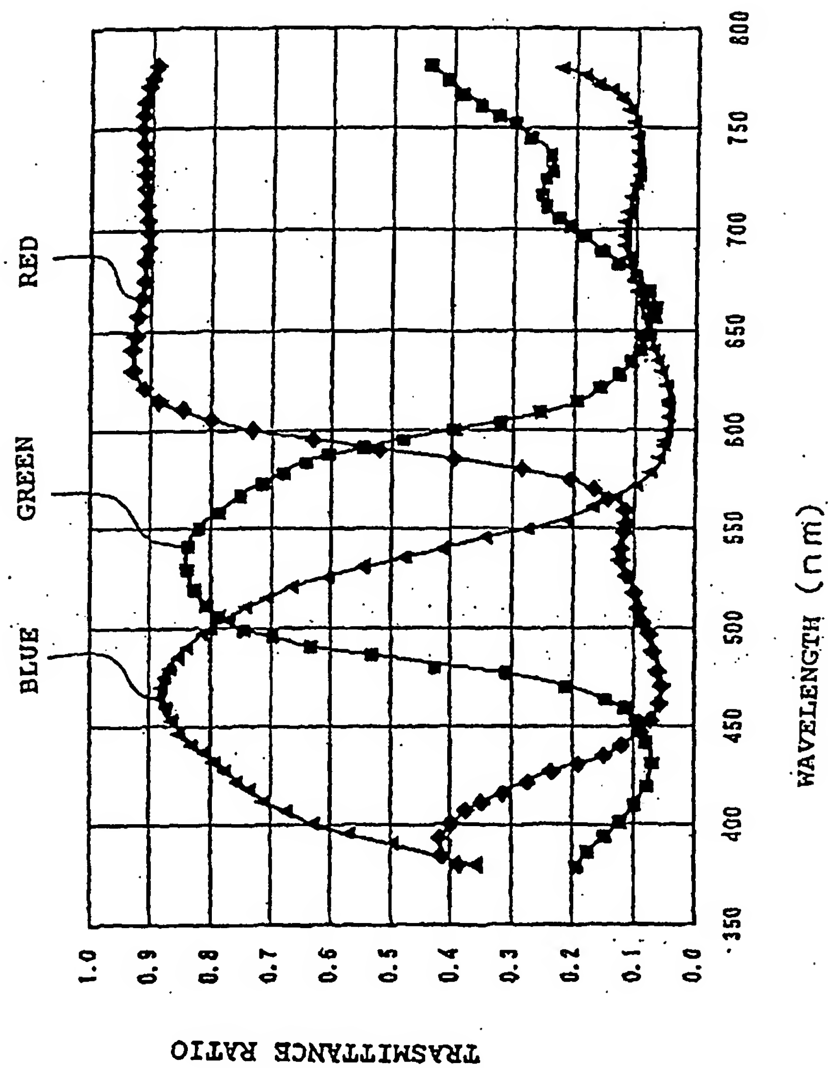
GREEN DISPLAY
WHITE DISPLAY
RED DISPLAY
BLUE DISPLAY
y
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
x

(B)

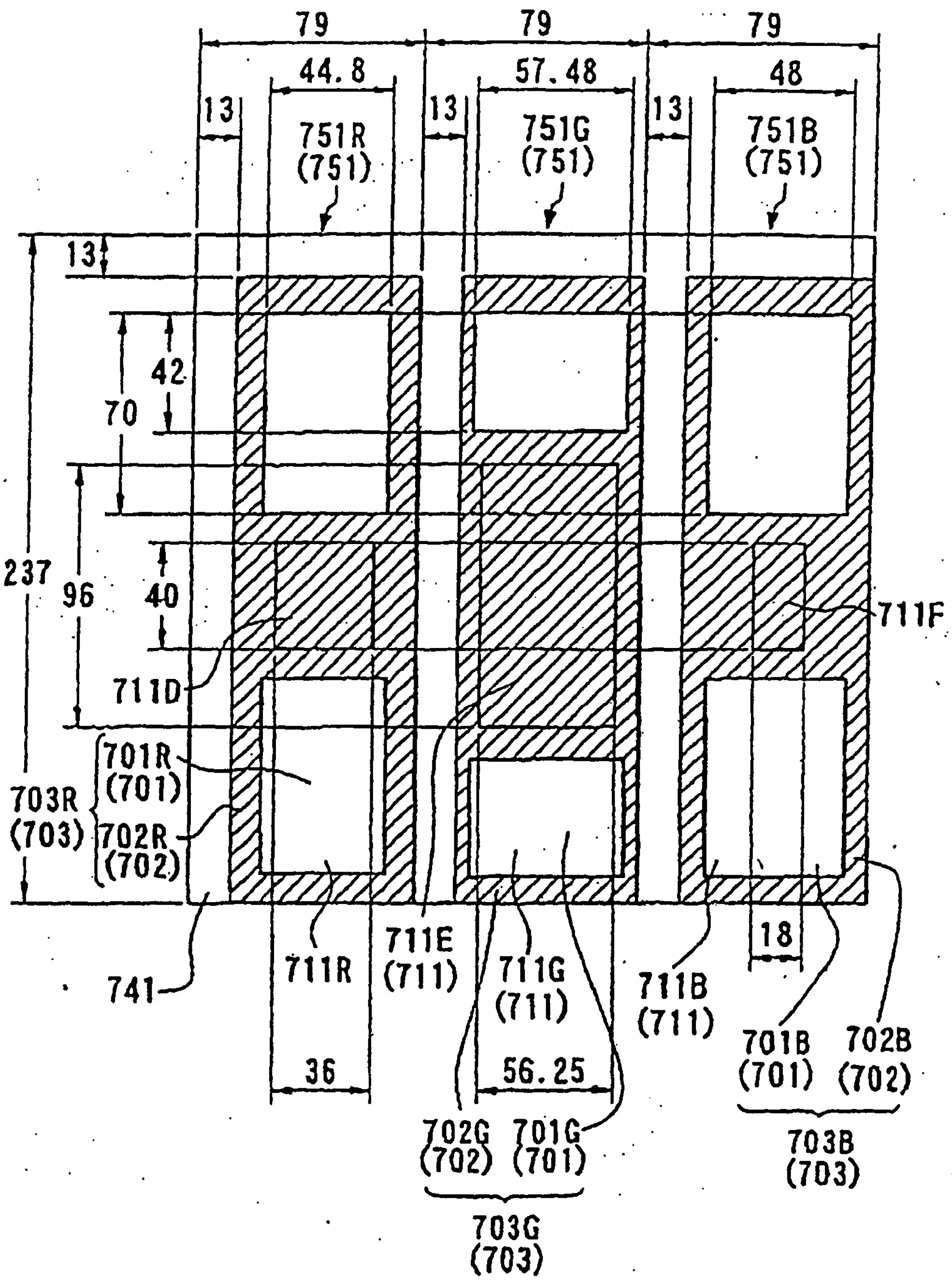


GREEN DISPLAY
WHITE DISPLAY
RED DISPLAY
BLUE DISPLAY
y
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
x

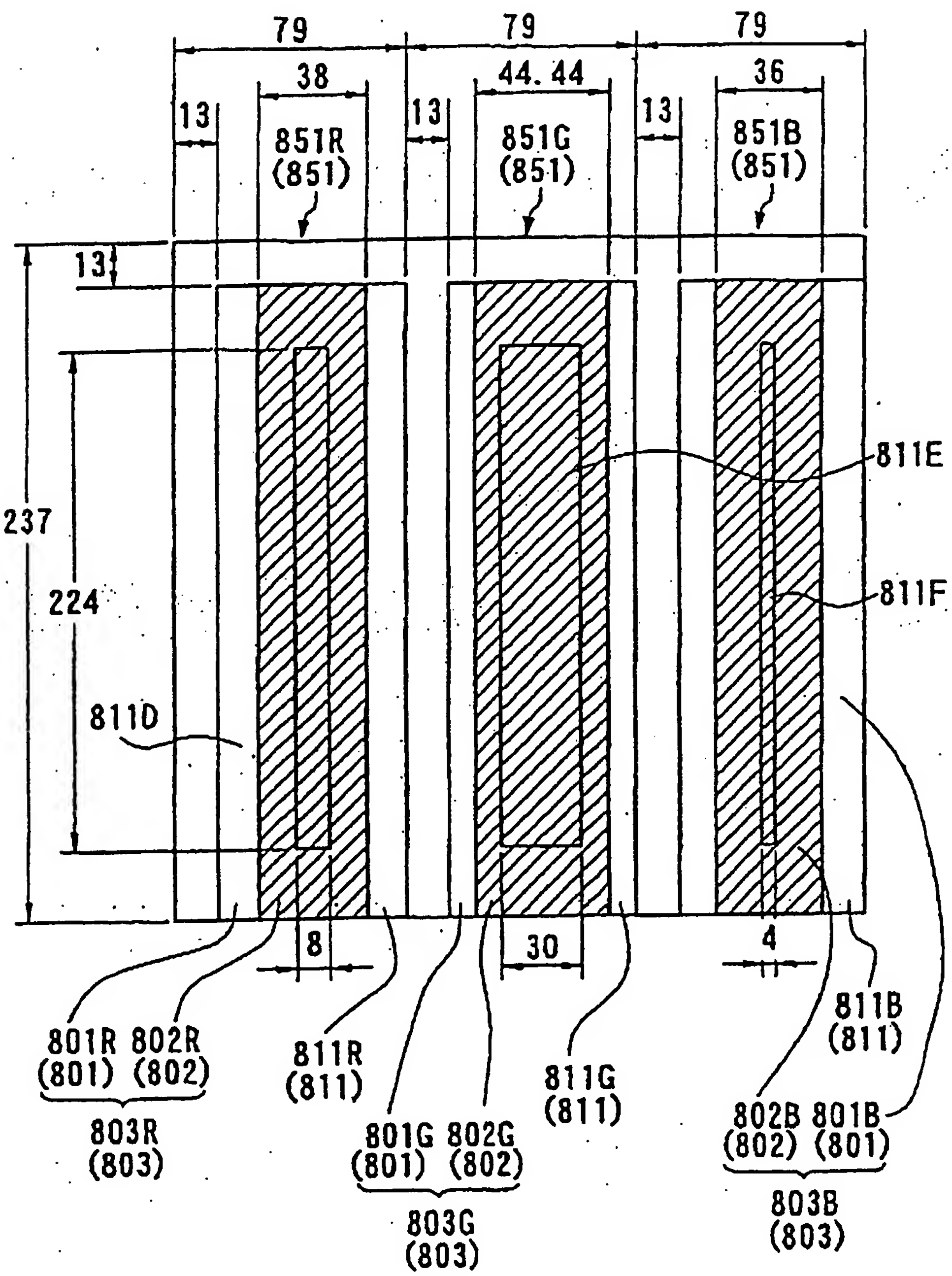
[FIG. 31]


RED
GREEN
BLUE
TRASMITTANCE RATIO
WAVELENGTH (nm)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
350
400
450
500
550
600
650
700
750
800

〔FIG. 32〕


79
79
79
44.8
57.48
48
13
13
13
751R
(751)
751G
(751)
751B
(751)
13
42
70
237
96
40
711D
711F
701R
(701)
703R
(703)
702R
(702)
741
711R
711E
(711)
711G
(711)
711B
(711)
18
36
56.25
702G
(702)
701G
(701)
703G
(703)
701B
(701)
702B
(702)
703B
(703)

〔FIG. 33〕


79
79
79
38
44.44
36
13
13
13
851R
(851)
851G
(851)
851B
(851)
13
237
224
811D
811E
811F
8
30
4
801R 802R
(801) (802)
803R
(803)
811R
(811)
801G 802G
(801) (802)
803G
(803)
811G
(811)
811B
(811)
802B 801B
(802) (801)
803B
(803)